THIS PAGE BLANK (USPTO)

PCT/GB 00 / 03431

10/070768 #2

The Patent Office

PATENTS • DESIGNS • COPYRIGHT • TRADE MARKS

REC'D 06 OCT 2000

WIPO PCT

INVESTOR IN PEOPLE

The Patent Office
Concept House
Cardiff Road
Newport
South Wales
NP10 8QQ

PRIORITY DOCUMENT

SUBMITTED OR TRANSMITTED IN COMPLIANCE WITH RULE 17.1(a) OR (b)

GB 00/03431

I, the undersigned, being an officer duly authorised in accordance with Section 74(1) and (4) of the Deregulation & Contracting Out Act 1994, to sign and issue certificates on behalf of the Comptroller-General, hereby certify that annexed hereto is a true copy of the documents as originally filed in connection with the patent application identified therein.

In accordance with the Patents (Companies Re-registration) Rules 1982, if a company named in this certificate and any accompanying documents has re-registered under the Companies Act 1980 with the same name as that with which it was registered immediately before re-registration save for the substitution as, or inclusion as, the last part of the name of the words "public limited company" or their equivalents in Welsh, references to the name of the company in this certificate and any accompanying documents shall be treated as references to the name with which it is so re-registered.

In accordance with the rules, the words "public limited company" may be replaced by p.l.c., plc, P.L.C. or PLC.

Re-registration under the Companies Act does not constitute a new legal entity but merely subjects the company to certain additional company law rules.

Signed

Dated 29 SEP 2000

F 1/77

Patents Act 1977
(Rule 16)

THE PATENT OFFICE
A
-7 SEP 1999
RECEIVED BY FAX

The Patent Office

07SEP99 E472313-1 D02884
P01/7700 0.00 - 9921042.9

1/77

Request for grant of a patent

(See the notes on the back of this form. You can also get an explanatory leaflet from the Patent Office to help you fill in this form)

The Patent Office

Cardiff Road
Newport
Gwent NP9 1RH

1. **Your reference** — P22111/ALO/CLF/JCO

2. **Patent application number** *(The Patent Office will fill in this part)* — 9921042.9 — -7 SEP 1999

3. **Full name, address and postcode of the or of each applicant** *(underline all surnames)*

   STOVE, George Colin
   41 Craiglockhart Park
   Edinburgh
   EH14 1EU

   Patents ADP number *(if you know it)* — 7734742001

   If the applicant is a corporate body, give the country/state of its incorporation

4. **Title of the invention** — "Radar Apparatus for Spectrometric Analysis and a Method of Performing Spectrometric Analysis of a Substance"

5. **Name of your agent** *(if you have one)* — Murgitroyd & Company

   "Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)*

   373 Scotland Street
   GLASGOW
   G5 8QA

   Patents ADP number *(if you know it)* — 1198013

6. **If you are declaring priority from one or more earlier patent applications, give the country and the date of filing of the or of each of these earlier applications and** *(if you know it)* **the or each application number**

Country	Priority application number *(if you know it)*	Date of filing *(day / month / year)*

7. **If this application is divided or otherwise derived from an earlier UK application, give the number and the filing date of the earlier application**

Number of earlier application	Date of filing *(day / month / year)*

8. **Is a statement of inventorship and of right to grant of a patent required in support of this request?** *(Answer 'Yes' if:*
   a) any applicant named in part 3 is not an inventor, or
   b) there is an inventor who is not named as an applicant, or
   c) any named applicant is a corporate body.
   See note (d))

   NO

Patents Form 1/77

Received 07-09-99 02:44pm From-+01413078401 To-THE PATENT OFFICE Page 03

Patents Form 1/77

THE PATENT OFFICE
A
- 7 SEP 1999
RECEIVED BY FAX

9. Enter the number of sheets for any of the following items you are filing with this form. Do not count copies of the same document

Continuation sheets of this form	
Description	39
Claim(s)	9
Abstract	1 DML
Drawing(s)	13

10. If you are also filing any of the following, state how many against each item.

Priority documents	–
Translations of priority documents	–
Statement of inventorship and right to grant of a patent *(Patents Form 7/77)*	–
Request for preliminary examination and search *(Patents Form 9/77)*	–
Request for substantive examination *(Patents Form 10/77)*	–
Any other documents *(please specify)*	–

11 I/We request the grant of a patent on the basis of this application.

Signature

Date

Murgitroyd & Company 6 September 1999

12. Name and daytime telephone number of person to contact in the United Kingdom

John Cooper 0141 307 8400

Warning

After an application for a patent has been filed, the Comptroller of the Patent Office will consider whether publication or communication of the invention should be prohibited or restricted under Section 22 of the Patents Act 1977. You will be informed if it is necessary to prohibit or restrict your invention in this way. Furthermore, if you live in the United Kingdom, Section 23 of the Patents Act 1977 stops you from applying for a patent abroad without first getting written permission from the Patent Office unless an application has been filed at least 6 weeks beforehand in the United Kingdom for a patent for the same invention and either no direction prohibiting publication or communication has been given, or any such direction has been revoked.

Notes

a) *If you need help to fill in this form or you have any questions, please contact the Patent Office on 0645 500505.*

b) *Write your answers in capital letters using black ink or you may type them.*

c) *If there is not enough space for all the relevant details on any part of this form, please continue on a separate sheet of paper and write "see continuation sheet" in the relevant part(s). Any continuation sheet should be attached to this form.*

d) *If you have answered 'Yes' Patents Form 7/77 will need to be filed.*

e) *Once you have filled in the form you must remember to sign and date it.*

f) *For details of the fee and ways to pay please contact the Patent Office.*

Radar Apparatus for Spectrometric Analysis and a Method of Performing Spectrometric Analysis of a Substance

This invention relates to radar apparatus for spectrometric analysis. In particular, it relates to pulsed radar apparatus for identifying and/or typecasting the composition of a substance by spectrometric analysis. The invention further relates to the use of the radar apparatus to locate and/or distinguish a substance from other substances. The invention may additionally be used to image a substance/feature and to monitor the movement of an imaged substance/feature in a subterranean environment, for example: water, oil, and/or gas movements below the ground surface or below the seabed.

The radar apparatus can be adapted for a variety of applications ranging from the large scale, such as sea-bed and ground penetrating applications for example precision mapping and classification of sea-bed materials and also soil, sediment and rock type mapping and classification, to the small scale such as powder and blood typecasting applications.

The scale (i.e., range and resolution) the radar apparatus operates on is determined to a greater or lesser extent by the geometry of the antenna apparatus relative to geometry of the surrounding resonant telescope cavity. It is also affected by the properties of the dielectric material cladding surrounding the antenna transmitting and receiving

Received 07-09-99 02:44pm From-+01413078401 To-THE PATENT OFFICE Page 05

elements. It is important that certain conditions are achieved during the set up of the apparatus if "standing wave oscillations" are to be obtained. In this respect it is important to selectively control the group velocity of the radiation as it is emitted or "launched" by the transmitter into the surrounding medium. In particular, for deep scanning it is important for the launch speed of the wave to be sufficiently slow to ensure that the wave can be accurately registered at a precise "zero time" location by the receiver after the pulse has been transmitted. The zero time position is the start position for range measurements and must be identified on the received radar signal to determine the true range represented by the received signal.

Setting up the standing wave oscillations for different time ranges or time windows such as, for example, 25 ns, 50 ns, 100 ns, 1000 ns or 20,000 ns, would all involve different zero time locations. Different time ranges are required to enable the different depth ranges required for certain precision mapping applications to be obtained. Accurate location of the zero time point is important and can be a difficult procedure: inaccurately pinpointing the zero time introduces a systematic shift in the location of all radar measurements. The invention registers the zero time location prior to the received radar signal being converted from analogue to digital form. This enables a more accurate zero time to be located than can be obtained by using alternative and/or conventional techniques involving a digital signal.

A blind spot of the order of 1 meter in close proximity (the near range) to the radar apparatus could generate an equivalent position shift in the radar map of

features detected. Such near range blind spots can thus be highly undesirable. By accurately locating the position of the zero time point in the received signal radar, such blind spots can be mitigated or obviated.

Although ground penetrating radars (GPRs) are already known as non-destructive testing tools their analytical capabilities have been restricted and imaging is often crude using conventional devices. Conventional radar systems which use electromagnetic waves to investigate the internal structure of non-conducting substances within the ground provide relatively low resolution. Furthermore, they are often unwieldy devices and require skilled technical operators.

The invention seeks to provide apparatus which is capable of being operated in three modes. The first mode of operation relates to typecasting unknown materials using their spectral characteristics; i.e., using energy-frequency parameters, and will be referred to hereafter as the "typecasting" operational mode. The second mode of operation relates to use of the equipment in the field, where it may be used to collect information on unknown materials, for example, their spectral characteristics and further to possibly image them and determine their location, this will be referred to as the "surveying" operational mode. The third mode relates to use of the apparatus to locate materials previously typecast, and to search for them in the field and will be referred to as the "searching" operational mode. The searching mode of operation is supported by suitable software which enables the field recognition process to be determined in near real time.

The inventor believes that a key feature of the invention is the set up of resonant conditions in the

transmitter/receiver apparatus. This is affected by the dimensions and/or the geometry of the transmitter cavity and the receiver cavity which substantially surround the respective transmitting and receiving antennae. In particular, the relative proportions of the length and width of the antenna element(s) to the length and width of the surrounding cavity are important. Ideally the internal diameter of a telescope cavity whose walls form the cathode element of an antenna is an integer multiple of the diameter of the internal antenna anode element, and similarly, the internal cavity length of the telescope cavity is ideally an integer multiple of the length of the antenna anode element. The resonant conditions may be further affected by at least partially cladding the antennae element(s) with a suitable dielectric cladding material. Furthermore, the selection of a suitable dielectric material to clad the transmitting and receiving antenna elements is believed to further assist in the near range focusing and in more accurately pin-pointing the zero time position, the start position for range measurements.

The invention seeks to provide radar apparatus having a transmitter which is capable of emitting a beam of electromagnetic radiation into a substance and a receiver which is capable of receiving electromagnetic radiation. The radiation is preferably a pulsed radar type signal. The radar signal may be provided by a conventional pulsed radar unit. The radar apparatus includes a suitable tuning means which is capable of controlling the spectral characteristics, for example the power and bandwidth, of the emitted radar signal. The spectral characteristics of the emitted radar signal are controlled so that by suitably irradiating a substance, a frequency response dependent on the

Received 07-09-99 02:44pm From-+01413078401 To-THE PATENT OFFICE Page 08

composition of the substance can be detected by the receiver.

Suitable substances whose composition and/or structure can be detected by the apparatus include solids, liquids and composite substances such as powders, soil or sediment. Liquid substances may be admixtures and/or emulsions (e.g. air/oil etc.).

The spectrometric analysis of the data acquired by the radar apparatus is performed on a computer which is capable of running a suitable software program to implement the required analysis.

The frequency response obtained by irradiating a substance displays characteristics which the inventor believes are at least partially dependent on the dielectric properties of the substance to be analyzed. The radar apparatus may further include suitable filter devices to control the spectral characteristics, for example bandwidth and/or polarisation, of the detected signal.

Optionally, the radar signal may be emitted into a chamber capable of holding a sample of the substance.

The emitted signal is controlled so that resonant conditions, i.e., standing waves, are set up within the radar apparatus. Preferably, the resonant conditions occur within the transmitting/receiving cavities surrounding the antennae. Further resonant conditions may be generated within the substance and/or within a cavity surrounding the substance. Such resonant conditions are established by selectively tuning the frequency of the emitted signal until the spectrum of the received signal indicates resonant conditions.

The radar apparatus is preferably configured so as to be capable of providing a highly collimated beam over a desired range.

The boundary conditions for resonant standing waves are at least partially dependent on the surface boundaries of the substance itself, and may be further affected by any internal structure within the substance. Composite materials, for example, may exhibit more complex boundary conditions which can enable the structure of the substance to be determined; for example, the degree of granularity of a powdered sample may be determined to some extent using the radar apparatus.

The invention thus seeks in particular to provide radar apparatus which is capable of providing a pulsed radar signal which can be tuned by the radar apparatus to exhibit at least one resonance condition.

According to a first aspect of the invention, there is provided radar apparatus which includes transmitter means for emitting a pulsed radar signal, receiver means for receiving a radar signal, filter means and/or tuning means to control at least one spectral characteristic of the emitted and/or the received radar signals, the radar apparatus including:

a transmitter cavity substantially surrounding at least one element of a transmitting antenna;

a receiver cavity substantially surrounding at least one element of a receiving antenna; and

a dielectric cladding material at least partially surrounding at least one element of at least one of said transmitting and receiving antennae.

Preferably, the radar apparatus further includes a lens substance provided at the aperture end of at least one

Received 07-09-99 02:44pm From-+01413078401 To-THE PATENT OFFICE Page 10

of the transmitting and/or receiving cavities thereby to focus radiation transmitted therethrough.

Preferably, the transmitter cavity comprises a telescope having a substantially cylindrical internal boundary wall forming the cathode element of the transmitting antenna and substantially surrounding the anode element of the transmitting antenna.

Preferably, at least one interior dimension of the telescope is proportional to at least one equivalent dimension of the anode element.

Preferably, the interior diameter of the telescope is an integer multiple of the diameter of the anode element of the antenna disposed therewithin.

Preferably, the interior length of the telescope cavity is an integer multiple of the length of the anode element of the antenna disposed therewithin.

Preferably, the receiver cavity comprises a telescope having a substantially cylindrical internal boundary wall forming the cathode element of the receiving antenna and substantially surrounding the anode element of the receiving antenna.

Preferably, at least one interior dimension of the telescope is proportional to at least one equivalent dimension of the anode element.

Preferably, the interior diameter of the telescope is an integer multiple of the diameter of the anode element of the antenna disposed therewithin.

Preferably, the interior length of the telescope cavity

is an integer multiple of the diameter of the anode element of the antenna disposed therewithin.

Preferably, the internal geometry of transmitter telescope and the receiver telescope are in the same proportion.

The transmitter and the receiver may be arranged with a longitudinal alignment of their respective antennae (transillumination mode) or in a parallel alignment (surveying/searching mode).

Preferably, the transmitter and the receiver are arranged so that the emitted and detected radiation is cross-polarised.

Preferably, at least one spectral characteristic of the received signal indicates a resonant condition.

Preferably, the transmitter is selectively tuned to generate at least one standing wave condition and/or resonant signal in the spectral response of the substance.

Preferably, the receiver is connected to the tuning and the filter means to enable the receiver to be capable of detecting the said at least one resonant signal.

Preferably, the filter means provided enable the receiver to distinguish the spectral response of the substance from the transmitted radiation from the transmitter.

Preferably, sufficient radiation is transmitted into the substance for standing wave oscillations excited within the substance itself to be detected by the

Received 07-08-98 02:44pm From-+01413078401 To-THE PATENT OFFICE Page 12

receiver.

The spectral characteristics of the emitted signal are preferably controlled in dependence on the dielectric properties of the substance. Further, the spectral characteristics of the emitted signal may be controlled so as to be dependent on the size of the substance. Preferably, the emitted and received signal occupies the ultra-wide band radio portion of the electromagnetic spectrum, preferably between 50 MHz and 2500 MHz. The received signal may range from 5 MHz to as high as 10 to 12 GHz for some substances.

Preferably, the radar apparatus further includes an analogue-to-digital (AD) converter which digitises an analogue signal output from the receiver. The radar apparatus may further include computational means for receiving the digitised output of the AD converter. The AD converter may provide at least one, preferably three output signals relating to the positional and/or compositional characteristics of a substance represented by the received signal. Preferably, the AD converter is capable of providing a fourth signal relating to voice data co-recorded with the acquired radar data.

The computational means may be provided integrally with the radar apparatus or alternatively, the apparatus may be connected to a computer so that the computer receives the digitised signal output of the AD converter.

Preferably, the computational means is provided with suitable software capable of performing spectral analysis on the received digitised signal.

Preferably, the spectral analysis determines at least one selected parameter to uniquely represent the substance.

The computer may be provided with a suitable storage means for the storage and retrieval of said at least one selected parameter representing the spectral analysis of the received signal.

Preferably, the said at least one selected parameter is determined in real-time during a data acquisition period.

The computer may be provided with display means for displaying at least one selected parameter representing the spectral analysis of the digitised signal. Preferably, such a display is generated and is refreshed in real-time.

In an alternative embodiment of the invention, the radar apparatus further includes a sample chamber. Alternatively, the transmitting and receiving cavities may form a sample chamber. The sample chamber may provide suitable resonance conditions in order to carry out a spectrometric analysis of a substance placed therewithin. The sample chamber resonance conditions may be to some extent dependent on the chamber's geometry, the sample size of the substance placed within it, and/or on any internal dielectric material placed within the sample chamber with the substance.

Preferably, the sample chamber is suitably shielded to prevent radiation leakage/contamination and is constructed to provide a dielectric medium between mirror points in the chamber. More preferably, the sample chamber is shielded so that radiation leaks are

substantially obviated. The shielding means of the chamber may comprise at least one layer of electrically insulating material and at least one layer of electrically conducting material. Preferably, the electrically conducting material is bonded to the interior side of the chamber.

The dielectric medium within the chamber is preferably a low dielectric medium, for example, air (ϵ_R=1). Alternative, or supplementary dielectrics include higher dielectric mediums such as, for example, distilled water (ϵ_R=81) or saline water at 100mg/l (ϵ_R=135).

The insulating material may be plastic, and the electrically conducting material may be a metal, for example, copper and/or aluminium and/or steel.

Preferably, the transmitter and the receiver are arranged in a cross polarised configuration in the chambered embodiments of the invention.

The chamber may be disposed substantially between the transmitter telescope and the receiver telescope when these are arranged in a transillumination mode.

Preferably, the chamber is placed equidistant from the emitting and receiving apertures of the telescopes when the telescopes are aligned in a transillumination mode.

The chamber may be geometrically constructed to maximise the propagation paths an emitted signal can be transmitted along through the substance.

Preferably, the interior geometry of the chamber provides mirror means for the transmitted signal to

undergo multiple internal reflections within chamber.

Preferably, the interior geometry of the chamber is substantially pyramidal.

The radiation may be selectively tuned by the radar apparatus to set up a resonance condition between said mirror means provided within the chamber. The mirror means thus ensure sufficient multiple internal reflections within the chamber occur for any sample placed therein to be suitably irradiated.

According to a second aspect of the invention, there is provided a typecasting method of spectrometrically analysing a substance. The typecasting method comprises:

configuring the radar apparatus according to the first aspect of the invention so that the signal received by the radar apparatus represents at least one resonant condition;

determining at least one selected parameter to represent at least one spectral characteristic of the received signal; and

suitably storing said selected parameter in a retrieval format, wherein said selected parameter is such that a substance which has substantially induced the spectral characteristics of the received signal can be uniquely represented in that parameter space.

Preferably, a method of typecasting a substance using a chambered radar apparatus embodiment as described hereinabove according to the first aspect of the invention comprises:

placing the substance into the chamber;

selectively tuning radiation transmitted into the chamber using a tuning control to generate resonant

conditions within the chamber;

detecting an analogue signal representing the spectrum of radiation set up under resonant conditions within the chamber;

converting the analogue signal into digital form; and

analysing said digitized spectrum to determine at least one selected parameter representing the composition of the sample placed within the chamber.

The typecasting method may further include storing the selected parameter in a retrievable electronic format.

According to a third aspect of the invention, there is provided a method of identifying an unknown substance using the radar apparatus according to the first aspect of the invention, which includes the method according to the second aspect of the invention and further includes the step of:

collating at least one parameter space previously determined and stored in a suitable memory means of a computer with the parameter space acquired which represents the unknown substance; and

correlating the two aforesaid parameter spaces to determine whether they are substantially equivalent.

According to a fourth aspect of the invention, the radar apparatus according to the first aspect of the invention is portable and can be used in either a scanning and/or surveying and/or search mode. A transmitter telescope and a receiver telescope according to the first aspect of the invention are arranged in a parallel configuration so that the aperture of the transmitter and the aperture of the receiver are directed in substantially the same direction.

The fourth aspect provides a means to distinguish a parameter space representing a particular substance from at least one other parameter space representing another substance, for example, if an object or substance is concealed or included with other objects and/or substances. The substance, which may be an object, powder, fluid etc., may be large scale: for example a ship on a seabed floor. Alternatively it may be medium scale: for example, a stone object in a field of earth or a leak of fluid from a tube. Smaller scale examples include, for example, distinguishing powdered substances, for example a narcotic or explosive dispersed within a legal powder medium. At the microscopic level, the apparatus is capable of detecting the presence of molecular structures. One medical application involves the detection of a blood composition condition which may be performed in vitro or in vivo.

Thus, one preferred embodiment of the invention provides a way of locating and identifying unknown objects/substances in field conditions; i.e., a surveying/searching mode. This preferred embodiment seeks to provide means to determine a parameter space which represents a substance in the presence of other parameter spaces representing other substances as the radar apparatus moves relative to the substances scanned. This enables a small object for example, to be located in a relatively larger spatial area.

Further, the type of substance/object may then be identified by correlation with selected spectral parameters stored in a database structure according to the second aspect of the invention.

The radar apparatus according to the fourth aspect of

the invention may be provided on a sea-vehicle. The sea-vehicle may be a surface craft, an underwater manned craft, a remote operated vehicle (ROV) or autonomous underwater vehicle (AUV) or towed platforms or device, for example, a TOWFISH™, or any sea-vehicle suitable for use in oil industry, marine, oceanographic, hydrographic, marine biological or fisheries applications.

Preferably, the radar apparatus is moved by the sea-vehicle at a rate of 1/4 knot to 1/2 knot. Preferably, the time interval should be less than 100 msec (i.e. the scan rate should be more than 10 scans per second). More preferably, the time interval for sampling data is between 50 msec (a scan rate of 20 scans per second) to 100 msec (a scan rate of 10 scans per second).

According to a fifth aspect of the invention, there is provided a method of determining the position of a hidden structure using the apparatus according to the first, and/or fourth aspects of the invention, in which the said selected at least one parameter data is converted into image data and is displayed on suitable display means.

Preferably, the method of locating features involves the steps outlined in the second and/or third aspects of the invention and further requires the step of locating the zero time position in the received radar signal.

Preferably, the received analogue signal is used to locate the zero time position prior to its conversion into a digital form.

Preferably, the image data is displayed in real time.

Preferably, the features imaged are concealed features. More preferably, the concealed features are subterranean features. The subterranean features may be located below ground level or below the sea-bed.

The preferred embodiments of the invention will now be described by way of example only and with reference to the accompanying drawings in which:

Fig 1 is a cross-sectional view of apparatus set up according to a first embodiment of the invention.

Fig 2 is a block diagram of the radar apparatus.

Figs. 3A and 3B are cross-sections of test chambers according to a further embodiment of the invention.

Fig. 4 is an internal plan-view of the test chamber illustrated in Fig. 3A.

Fig. 5 is a cross-section of a telescope according to a second embodiment of the invention.

Fig. 6A illustrates the arrangement of the radar apparatus 1 suitable for use in the field or staring mode of operation in which the transmitting and receiving telescopes are provided in accordance with a further embodiment of the invention.

Fig. 6B illustrates an arrangement of the radar apparatus 1 in which the transmitting and receiving telescopes according to the third embodiment of the invention are arranged in transillumination mode.

Figs. 7A and 7B illustrate various circuits incorporated into the Analogue-to-Digital converter of

the invention.

Figs. 8A to 8D are sketches which illustrate various embodiments of the invention suitable for the remote detection and imaging of substances/objects.

Fig. 9 is a sketch illustrating an embodiment of the radar apparatus suitable for sea-bed scanning.

Fig. 10 is a sketch illustrating another embodiment of the apparatus suitable for sea-floor scanning.

Fig. 11 is an image recorded using the radar apparatus according to the invention.

Referring now to Fig. 1 of the drawings, a cross-section of radar apparatus according to a first embodiment of the invention is illustrated.

The radar apparatus shown generally at 1 consists of transmitter telescope component 2 and a receiver telescope component 3 aligned substantially coaxially with a chamber 4 provided in co-alignment therebetween.

The transmitter telescope 2 and receiver telescope 3 each consist of a cavity 5a and 5b respectively, for example a hollow tube or pipe. Within the tube 5a, an anode 6a and cathode 7a form a transmitting antenna 8a which is disposed in longitudinal alignment with the tube axis XX'. Within tube 5b, an anode 6b and cathode 7b form a receiving antenna 8b which is disposed in longitudinal alignment with the tube axis XX'.

Within each tube 5a,5b, the anodes 6a,6b and cathodes 7a,7b are substantially surrounded by a cladding

material selected for its dielectric properties. For example, the antennae 8a,8b can be immersed in distilled water which is used as a dielectric cladding. Other alternatives include mixtures of distilled water and sand, or any other substance having the desired dielectric properties. Each tube 5a, 5b is suitably sealed at each end 12a, 13a and 12b, 13b respectively. A suitable sealant is, for example, a resin or other insulating substance.

Focusing means 9a, 9b are provided adjacent to the chamber 4. Each of the focusing means 9a or 9b comprises a lens of a selected geometry and dielectric composition to enable the radiation emitted/received by the respective transmitting antenna 8a or collecting antenna 8b to be converged/diverged as it enters/exits the chamber 4 respectively. For example, in the first embodiment of the invention, the lenses 9a, 9b of the transmitter and receiver respectively are both selected to have a wax composition with a high resistivity, for example, of the order of 10^9 Megohm-meters.

The relative dimensions of each anode 6a,6b to the corresponding cathode 7a, 7b and the surrounding dielectric material and/or tube 5a,5b are determined to be fractionally proportional to each other. For example, the width of the anode 6a is proportional to the width of the cathode 6a and to the interior diameter of the tube 5a and also so that the length of the anode 6a is proportional to the overall length of the tube 5a.

It is believed that such geometrical scaling between the antenna and the surround cladding assists the formation of standing wave oscillations. Standing wave oscillations set up within the dielectric material

07-09-99 02:52pm From-MURGITROYD +01413078401 T-645 P.22/66 F-565

contained within the transmitting tube 5 can assist in the intensification and collimation of the emitted radiation. Under such conditions, the transmitter telescope 2 provides a means of generating a resonant and collimated beam of radiation at selected wavelengths which the receiver telescope 3 is capable of detecting.

The overall geometry of the transmitter telescope 2 and receiver telescope 3 are therefore related to the size and scale of resolution required. The dielectric properties of the cladding material selected to surround the antennas 8a, 8b are also important in this respect as these will affect the group velocity v_g of the radiation emitted/received.

In the embodiment illustrated in Fig. 1, the transmitter telescope 2 and receiver telescope 3 are arranged in coaxial alignment so that the sample chamber 4 is transilluminated. In other embodiments described in more detail hereinbelow, however, the transmitter telescope 2 and receiver telescope 3 may be disposed substantially parallel and are not in a transillumination configuration (see for example, Figs. 6A, 8A to 8D, 9 and 10). The selection of appropriate telescope, antenna, and aperture sizes enables larger scales to be resolved, for example, objects/substances which are underground or underwater (see for example, Figs 8C, 8D, 9 and 10).

To typecast a substance by determining its spectral characteristics, other selection criteria may be used to determine a suitable antenna cladding material and the relative telescope dimensions and overall size. In each case the selection objective is to ensure sufficient spectral detail is obtained at the desired

Received 07-09-99 02:44pm From-+01413078401 To-THE PATENT OFFICE Page 23

resolution and scale. To ensure optimum conditions, it is preferable for the widths/lengths of the telescope tubes 5a,5b to be integral multiples of the widths/lengths of the internal antennas 8a and 8b respectively.

Returning to Fig 1, in the first embodiment of the invention the radar equipment 1 is operated to typecast/identify a sample 10 placed within the chamber 4. The chamber 4 in this embodiment is disposed in two parts: a lower portion 4a attached to the transmitter 2 and an upper portion 4b attached to the receiver 3. The sample 10 is placed in the lower portion 4a. In one embodiment, the chamber has an internal diameter of 40 mm and an internal depth of 40mm above the tube base. The sample portion of the chamber 4a is positioned within 300mm from the electronic transducer pod.

In this embodiment, the tubes 5a,5b each have an internal diameter of 16mm, and the chamber is positioned so that the overall inner transmission length of the transmitter tube 5a and chamber portion 4a is 330mm and the overall receiver length of the receiving tube 5b and chamber portion 4b is 295mm. The measurements in each case are parallel to the direction XX' and are measured from the contact interface between the lower chamber portion 4a and the upper chamber portion 4b when the chambers contact each other in the transillumination configuration. For required internal chamber volume, the dielectric lenses 9a, 9b are selected to optimise the convergence/divergence of radiation emitted by the telescopes 2,3 and the sample chamber portion 4a is located within a maximum distance from the transmitter 2, preferably no more than 300mm.

In the embodiment illustrated in Fig. 1, each antenna 8a, 8b is a multi-folded YAGI array with two insulated groups containing a plurality of individually screened high quality copper elements in the longitudinal tube plane XX'. Each array is filled with the distilled water to make a dielectrically clad bistatic antenna pair. The above configuration enables an optimum impedance match to be obtained at 50 ohm.

The radiation emitted by the transmitting antenna 8a is focused by means of the wax lens 9a so that the sample 10 placed in the lower portion of the chamber 4a is irradiated. Each wax lens 9a, 9b in this embodiment extends 4mm into the base of the chamber portions 4a, 4b respectively. The receiving portion of the chamber 4b is filled with a suitable dielectric, for example, air. The radiation is refocussed by the wax lens 9b into the receiving telescope 2 where it is detected by the receiving antenna 8b.

In this embodiment, the size of the chamber 4 limits the size of objects to be typecast: apart from this limitation a variety of substances may be typecast, ranging for example, from solid materials or composites, liquids, gases, soils, sediments or powder samples. For example, wood powders, soils, flours and oils. Both organic and non-organic substances can be typecast.

As an example, if the total volume of the sample chamber 4 is 45ml, a sample of, for example, 25ml of the substance to be typecast may be placed within the lower portion of the chamber 4a. Air occupies the remaining 20ml volume of space inside the upper chamber portion 4b.

To ensure that stray e.m. radiation is reduced to a minimum, suitable e.m. shielding is provided. For example, by selecting a conductive, metallic substance (e.g. aluminium) to form the tubes 5a,5b and chamber portions 4a,4b and/or by further sheathing the metallic substance with a suitable insulating material (e.g. plastic). The provision of a layer of insulating material and conductive material is as is known in the art such that stray e.m. fields etc. are substantially eliminated.

The transmitter telescope 2 is used to generate a resonant collimated beam of pulsed radar signals. These pulsed signals are set up and controlled by the pulse generator unit 21 (see Fig. 2). In the first embodiment, the band width is of the order of 2 MHz to 200 MHz, i.e., is a relatively narrow bandwidth. A large enough time window is provided to ensure that sufficient reflections have occurred within the telescopes 2, 3 and the chamber 4. For example, a time window of 16ns can be used with a pulse interval time of 100ms.

Referring now to Fig. 2, a block diagram illustrates certain components of the radar apparatus. The pulse generator unit 21 is powered by a power supply means 20 and suitable I/O means to transmit and receive pulsed signals. The emitted pulse characteristics, for example, the pulse profile, width and duration are determined by a pulse control means of the pulse generator 21. A received signal inputted to the pulse generator 21 from the receiver telescope 3 in analogue form is digitally converted by conversion means 22, 25 prior to appropriate signal processing by processing means 23. A suitable display means 23 such as a VDU (not shown) and further storage means 24 may

additionally be provided.

The power supply means 20 may be a mains supply, or alternatively, especially in portable embodiments of the invention, be a generator and/or a battery supply. The power supply means 20 may be provided internally within the pulse generation unit 21 or externally. In this embodiment, the power supply means 20 is a 12 volt DC supply which may be a mains supply converted to 12 V DC, or alternatively, especially in portable embodiments of the invention, be a 12V generator and/or a 12V DC battery supply.

The radar pulse generator 21 is of a conventional type including appropriate electronic circuitry for signal generation and control so as to be capable of providing a controlled signal pulse to the transmitter telescope 3.

The signal processing and monitoring means 23 may be alternatively provided by a suitable pulse generator unit 21 which is capable of running an appropriate software suite to perform the invention. However, it is preferred that the software be installed on an appropriate computer, for example a laptop or personal computer which has a suitably powerful processor, e.g. a Pentium-type chip, and suitable memory means. To ensure adequate storage of the identifying parameters determined by the invention for each typecast substance for example, a computer 23 which has at least one data storage means 24, for example, a hard drive, disk, tape and/or writable CD drive.

The analogue signal inputted into the receiving means of the pulse generator is converted to a digital signal by the conversion means 22 which is here an Analogue-to

-Digital (AD) converter. The conversion can be controlled by a control unit 25. The AD converter 22 outputs the digital signal to the signal processing means 23.

The AD converter 22 is specifically designed so that in use it is capable of receiving at least three signal inputs, and a fourth signal input for example a voice data input may be additionally provided.

Figs 7A and 7B illustrate some of the circuitry of the AD converter 22. The component values provided are not meant to be limiting in any way and may be substituted for equivalents where appropriate. The key features of the AD converter enable real-time analysis of

i) a positioning fix sign - or chainage mark, this enables the location of a substance/image to be determined;

ii) imaging signal information;

iii) typecasting information - i.e., the spectral characteristics of the scanned substance/object;

iv) a voice over to be further recorded from user via a suitable microphone as a digital signal.

During use of the radar apparatus 1 the AD converter converts the em radar signal from analogue format to 12-bit digital signal and combines this with a synch pulse and electronic fix data. The signal is buffered and synchronised with a 16 bit computer signal to condition the data. Image data are converted into 8-bit image files.

The bandwidth of the signals received depends on the size and configuration of the antennas 8a,8b and the sample chamber 4. If the sampled substance is to be typecast, i.e. if its resonant spectral characteristics

are to be determined and stored in a database, typecasting is achieved by comparing the spectral characteristics of the signals detected from the apparatus 1 when the sample chamber 4 is empty with the signal detected under resonant conditions when a substance to be typecast is placed within the chamber 4.

It is thus important to provide a sufficiently long time window for the radiation pattern created within the test chamber 4 to become sufficiently intense to set up resonant conditions within a sample, whether the sample is placed within the test chamber 4 or is recorded *in situ* in the scanning mode of operation such as is described in more detail hereinbelow. The radar apparatus 1 includes appropriately sensitive controls to ensure the intensity and other spectral characteristics, for example, bandwidth and polarisation of the emitted radiation is suitably selected so that a spectral response is sufficiently induced within the sample to be detected. The detected signal is then analyzed by computational means connected to the AD converter 22 of the radar apparatus 1 and/or in conjunction with a user of the apparatus 1, the emitted radar pulse being tuned either manually by a user or according to computationally selected criteria so that the detected signal indicates that at least one resonant radiation condition is present.

The signal which is detected under such resonant conditions is then further analyzed by the spectrometric software provided on a suitable computer to determine at least one parameter forming a parameter space which uniquely identifies, or substantially uniquely identifies, the substance. By determining a unique parameter space representing the substance and

suitably storing it in a retrievable electronic form, the subsequent identification of the substance is possible. Either a further software program can be used to collate previously stored parameter spaces with a parameter space relating to an unknown substance, or a user can subsequently identify the substance by collating parameter spaces until a correlation is sufficiently established to identify the unknown substance. A series of runs may be used to determine an appropriate set of parameters to represent the differences between the two spectra. These parameters then uniquely represent that particular substance and can be stored in an appropriate database.

Fig 2 indicates the three potential modes of operation which can be used for typecasting. The first is a stationary scanning mode in which the radar apparatus incorporates a test chamber such as Figs 1, 3A and 3B illustrate. The second mode relates to the telescopes 200 such as Fig. 5 illustrates, being deployed in an an axially-aligned transillumination configuration such as Fig. 6B illustrates. The third mode of operation relates to the telescopes 200 being deployed in a parallel configuration with the telescope apertures facing the same direction and the received signal having been deviated back towards its source direction (e.g. reflected or backscattered) such as Figs. 6A, 8A to 8D, 9 and 10 illustrate. The telescope apparatus may be deployed in a stationary configuration or the telescope apparatus may move relative to the substance/area to be scanned or the substance/area may be moved relative to the telescope apparatus.

To set up appropriate conditions in order to typecast material, the following technique is used. To provide optimum control during the set up procedure, the best

method found by the inventor is to switch off the Automatic Gain Control and the Time Varying Control of the pulse generator 21. A reasonable received signal bandwidth is then established by suitable selection of the cut-off frequencies of a high-pass filter and low-pass filter. For example, between 40 Hz and 3.2 kHz.

A large enough time window is selected for sampling to allow a sufficient number of resonant ringing reflections through the scanned substance/object to have occurred to enable significant spectral relationships for each sampled substance to be established. The inventor found that in the case where a 25ml sample was placed in the chamber portion 4a, and 20ml of air was left in the sample chamber portion 4b, that a suitable time window was approximately 16ns. Increasing the minimum time window to, for example, 25ns, further enables sufficient resonant effects to be established and tested. The sampling interval, or scan rate, is selected to allow a sufficient pulse dwell time to enable resonance through the sampled substance to be optimised. In this embodiment, sampling was optimised with a sampling interval of 100ms (10 scans per second) to ensure that consistent results were obtained on repetitive tests. As a lower limit, the sampling interval should not be less than 50ms; i.e., the scan rate should not exceed 20 scans per second.

A second embodiment of the invention is illustrated in Fig. 3A, and a variation of this embodiment is illustrated in Fig. 3B. Fig. 3A shows a cross-section through a sample irradiation chamber 100 which has a preferred pyramidal geometry. Fig. 3B shows a cross-section through a sample irradiation chamber 100 which has a taller structure than that illustrated in Fig. 3A. Fig. 4 shows an overhead view of the embodiments

illustrated in Figs. 3A and 3B indicating the antenna configuration.

The cross-section along lines X-X' of Fig. 4 is illustrated in Fig. 3A. In Fig. 4, a transmitting antenna 101 and a receiving antenna 102 are directly provided within the chamber 100. Fig 3A shows the configuration of the transmitting antenna 101 in profile. A cathode feed connector wire 111 connects a cathode half of the transmitting bowtie dipole element 115a to the pulse generator 21. An anode feed connector wire 112 connects the anode half of the transmitter bowtie element 115b provided on the opposite internal face of the chamber 100 to the input of the pulse generator 21.

Fig. 4 illustrates the orientation of a receiving cathode bowtie dipole component 120a and connecting cathode feed connector wire 118 and a receiving anode bowtie dipole component 120b and connecting anode feed connector wire 119.

To increase the detection of cross-polarised reflections and to reduce the detection of other reflections, the receiver dipole components 120a,120b are orientated at 90° to the transmitter dipole components 115a,115b.

To ensure that a sample of material 116 placed within the chamber 100 (as Fig. 3A and 3B show) is sufficiently irradiated, the chamber 100 is provided with a suitable geometry to enhance the internal reflection and is suitably sealed to eliminate radiation leaks. Alternatively the chamber and/or transmitter/receiver tubes are vacuum sealed. A wall 113a or base 113b of the chamber 100 is configured so

that access to the interior is provided so as to enable the sample 116 to be placed inside. For example, the entire base 113b of the chamber 100 may be detachable.

Radiation shielding of the interior and the elimination of any radiation leaks from the interior is provided by the selection of suitable construction materials for the chamber 100. For example, the walls 113a and base 113b of the chamber 100 may be constructed from an insulating material such as plastic, and may be bonded externally or internally to an electrically conducting material such as copper 114. Alternatively, the base 113b may be made of a metallic substance to optimise base reflections.

In the Fig. 3B chamber, to ensure that the optimal number of reflections occur in the chamber interior, the rectangular side walls 122 are preferably provided with a metallic inside surface. This enables omni-directional backwall and base reflections from the transmitted radiation to penetrate the sample. The geometry of the chamber 100 is preferably selected to maximise the irradiation of the sample. As Figs. 3A and 3B show, the primary direction of the radiation pattern is orientated to and from the walls 113, base 123 and the sample 116.

Fig. 5 is a cross-sectional view of a telescope 200 which can be deployed either as a receiver 201 or as a transmitter 202 according to a third embodiment of the invention. A pair of such telescopes 200, one acting as the transmitter 202 and the other acting as the receiver 201 may be disposed substantially parallel to each other with their apertures pointing in the same direction. In use, the pair of telescopes 201, 202 are

orientated substantially normal/perpendicular to a desired scanning plane/track. This configuration assists in remotely locating substances such as, for example, buried objects. Alternatively, the telescopes can be co-aligned but may be separated so that they can transilluminate an object placed along the common axis of the telescopes such as Fig. 6B illustrates. The telescopes in such a configuration are optically aligned to face one another and are placed at an optimal focusing separation with the test substance/object located mid-way between the two sensors in order to achieve a balanced transillumination effect.

At the front end 203 of the telescope 200, a focusing system is provided by a suitable lens device 204, for example of the type of a Fresnel Zone Plate (FZP) lens. The FZP lens comprises two concentric slit-ring apertures (224, 225) separated by a ring spacer 226, for example a metallic (e.g. polished brass) front-end internal reflecting ring (226). The main body of the telescope 200 consists of a tube 227, preferably having a reflective metallic composition for example, polished brass or stainless steel. A back wall reflector 232 is provided in the form of a curved metallic ring (again polished brass or any other suitably reflective material may be used) which is bonded suitably to the tube 227 and to the cathode connector 233. Through the centre of the backwall reflector 232 protrudes the anode element 230, which is preferably a narrow hollow tube element, for example, comprising copper, and which is separated from the grounded cathode walls of the telescope 200 by insulating material 231.

The diameter D_A of the anode element 230 is an exact

multiple of the internal diameter D_T of the telescope tube 227. The anode element 230 also protrudes into the interior of the tube 227 by a distance L_A which is an exact multiple of the total reflecting distance $L_T$from the back wall reflector 232 to the front wall reflecting ring 226.

For example, with an anode width of 2 mm, and a tube inner diameter of 10 mm gives a ratio for $D_A:D_T$ of 1:5. Ideally, the ratios between the anode diameter and the tube diameter are integers and similarly the ratios between the anode length and the tube length are integers. In this case, an anode length L_A of 19.05mm and a tube inner length L_T of 190.5 mm between the back wall internal reflector 232 and front wall internal reflector 226 gives a longitudinal standing wave ratio parameter of $L_A:L_T$ of 1:10. This balances the lateral ratio parameter $D_A:D_T$ of 1:5 to achieve optimum standing wave resonance in the tube, before the wave is launched through the aperture.

These proportions are optimised to provide an ideal resonant reflection conditions in the telescope 200. The amplification effect is further optimised by the appropriate selection of a dielectric cladding material 228. The cladding material 228 has a high dielectric constant to provide an optimum resonant amplification through the dielectrically clad antenna system. An anode feed wire connects the anode element connector 236 to a highly resistive (e.g. 75 Ω) lead cable 235. The back reflector 232 is grounded by connecting a ground wire from the lead cable 235 to the cathode element connector 237.

The procedure used to set up the optimum conditions for typecasting is now outlined for the second and third

embodiments of the invention.

With the equipment outlined in Figs. 2 to 4, the main system components are the pulse generator 21 with oscillator set-up control functions; the AD processing module 22 for the input signal with a parallel port input into a computer 23 (which in this embodiment is a conventional portable laptop computer) and the radar transmitter 115 and receiver 120 illustrated in Figs. 3A, 3B and 4 which are incorporated into the chamber 100. This embodiment of the radar equipment can thus be set up to scan and typecast the samples, in particular powder samples, by transillumination.

Alternatively, the radar equipment may be arranged in a transillumination mode without any specific chamber being provided, such as Fig. 6B illustrates. In this mode, the apparatus provides a means to image the internal composition of, for example, baggage on a conveyor belt. In such an application, the sensor telescopes 2,3 are arranged on either side of the belt to optimally irradiate baggage as it moves along the belt. Metallic reflectors may be further provided below the belt and around the sides/roof of any surrounding shield. Substances could be detected by scanning baggage and comparing recorded signal parameters with parameters representing previously typecast substances.

Alternatively, the equipment may be arranged remotely from a sample and detect reflections, preferably cross-polarised from a remote object/substance. For example, Fig 6A is a schematic diagram illustrating the arrangement of the receiving and transmitting telescopes according to the third embodiment of the invention in a manner suitable for remotely detecting

objects and/or substances. The transmitter telescope 201 and the receiver telescope 202 may be mounted on suitable land and/or sea vehicles. For example, Fig 8A illustrates how the apparatus may be mounted on to the rear or front of a land vehicle. Alternatively, the apparatus could be provided to protrude through the floor or hull of a sea-vehicle such as Fig 8D shows. Depending on the scale of the telescopes, the apparatus may be highly portable for applications, such as Figs 8B and 8C illustrate. Fig 8B shows a portable device suitable for operation on land whereas Fig 8C shows a portable device suitable for submerged operation.

Fig. 9 illustrates how a transmitting telescope 201 and a receiving telescope 202 may be arranged in parallel along a tong 250 forming part of a submerged moveable platform 280 which can be attached to the front of a remotely operated vehicle 260 suitable for operation on a seabed 270.

Fig 10 illustrates how a plurality of pairs of arrays of transmitting telescopes 201 and receiving telescopes 202 may be arranged on the underside of pontoon-type supports 300a, 300b for use with a semi-submersible platform or sea-vehicle. Such a configuration of the radar apparatus enables sea-bed sensing, imaging and typecasting of materials for the oil industry.

The telescope pairs are spaced along the pontoon, preferably equidistant from adjacent telescope pairs in the array. At least one array of receiving telescopes is arranged parallel to the corresponding array of paired transmitting telescopes to enable wide angle reflection and refraction (WARR) sounding. At least one such telescope pair array is provided on each pontoon, for example, two per pontoon are illustrated

in Fig. 10, to form a total of eight arrays of telescopes 200. Using this apparatus, a variety of large scale structural and compositional information may be collated from and within the seabed, for example, the apparatus may be used in such a "searching mode" to detect subterranean and seabed features.

The inventor has detected shipwrecks and the apparatus may be suitable for the detection of oil and gas deposits using this apparatus. Features such as shipwrecks may be buried deep below the seabed. Although it is possible to detect such features with a single pair of telescopes over a relatively small search area, an array of telescopes, and preferable a multiple array of telescopes can be used. Multiple arrays could scan many lines in one forward sweep covering a large search area in a short space of time.

Furthermore, by allowing the apparatus to remain in situ and scan a fixed area for a period of time, (i.e. to "stare" in the surveying mode) it is possible to record a series of images indicating movement of substances such as liquids (e.g oil) and gases (e.g., natural gas seepage).

In the WARR configuration illustrated in Fig 10, the arrays provided operate in tandem, for example, the transmitting array 310a will emit a signal which is reflected and recorded by the receiving array 320b, and the transmitting array 320a will emit a signal which is preferably recorded by the receiving array 310b, etc. This enables a plurality of lines 330 to be scanning efficiently along the sea-bed. In the illustrated example, nine lines 330 can be scanned. In WARR mode any telescope can be selected as a transmitter and

reflections can be received from any receiving telescope in any specific order and sampling time to allow increasing Tx and RX (see Fig. 10) separation for triangulation and precision mapping reasons. If this triangulation procedure is carried out, then a detailed table of dielectrics can be produced including depths, radar velocities, interlayer thicknesses, interlayer velocities, and interlayer dielectric constants.

The size of the aperture of the telescope 200 is optimised to suit the path length and the beam collimation requirements. For deeper sounding and longer path lengths it may be necessary to vary the focusing means. For example, by fitting narrow apertures with a range of optional circular slits. These can then be fitted to the telescopes to provide focusing at the optimum near/far field ranges. The focusing means selection criteria follows that known in the art from radar design and selection procedures and are based on simple geometric, timing and platform speed considerations.

For the field operation modes, typical land vehicles include ATVs, small robotic platforms, man-portable and/or hand operated or track or rail mounted for tunnels or mines, or man portable operated from raised bucket platforms for scanning vertical wall surfaces of buildings, tunnels or bridge structures. Typical sea-vehicles include inflatables, hovercraft, Dory work boats, tug-boats, hydrographic/seismic-type survey vessels, or oil-industry semi-submersible platforms with pontoons suitable for mounting large tube-arrays, or ROVs, or autonomous underwater vehicles (AUVs), or Jack-Up Platforms or Drilling Rigs or Stand-Alone Production Platforms. The telescopes 200 are provided substantially vertically and are orientated so that

they can stare into the ground/seabed, at depths capable of resolving oil and gas reservoir structures. In a specific example for detecting sub-seabed substances, the sensor telescopes 201,202 may be of the order of 24m by 8 inches internal diameter and comprised two 12m long by 8 inch (internal diameter) high quality steel oil tube casings welded to another two 12m by 8 inch casings to make a pair of large transmitting and receiving telescopes some 24m long. Such a geometry for the telescope 200 is believed by the inventor to have a natural resonance which amplifies the radar signal by a factor of 180.

The apparatus may be further mounted on air/space vehicles, for example, small helicopters or remotely powered vehicles (RPVs) such as model aircraft, or balloons, blimps or piloted auto-gyros. Spaceborne platforms may be used for subsurface geological investigations of moons, comets and/or other planets.

It is possible to classify and map oil, water and gas reserves deep underground without the need for drilling. By staring deep underground, it is possible to monitor oil, water and gas movements and to classify oils already typecasted and held in spectral databases of oil types.

Other applications include the detection of explosives, contraband substances, and in particular narcotics, as well as the typecasting of rock, soil, sediment and ice cores.

The telescopes are capable of providing imaging information when the received signal is appropriately displayed. In this respect the telescopes are believed to operate similarly to a laser, except that radio

waves are resonated in a highly dielectric medium and with a carefully selected dielectric medium and with a carefully selected dielectric lens aperture with concentric circular focusing slits. With a 3mm aperture, it is possible to focus the beam from 3mm from outside the central aperture to infinity, like a pin-hole camera.

An example image is provided in Fig 11. The image represents a scan of a short cylindrical core of gold in a quartzite seam indicated at A. The dimensions of this short scanned portion are 280mm and the diameter of the gold core is approximately 40mm.

The vertical dimension reflects the time domain and the horizontal scale has been rectified to represent the length of the core scanned by the moving telescope pair. The top of the image is 0ns. Further time delays represent signals reflected from deeper within the sample core. Looking down through the core reflections recorded to about 5.4ns. Two further harmonic reflections are provided which provide information on surface roughness of the core and arise from too much initial power being used to generate the radar pulse. The first reflection lies from approximately 7ns to 13ns in time range and the second multiple surface reflection shows an enlarged portion of the core from 17ns to 25ns, the limit of the 25ns time window selected.

The selection of appropriate circular slit apertures 224,225 and ring spacings 226 and the choice of dielectric filler 228 which launches the wave enables the internal structure of the core to be perceived. If the anode length is a fraction, for example $1/\alpha$ or in this case 1/10th of the total internal telescope tube

227 length, then the time delay of the radar beam (i.e., the time from emission to detection) is multiplied by the reciprocal α of the fraction $1/\alpha$; ie., the actual time delay $T_D = \alpha \times$ the expected time delay T_E, where T_E is as is given in conventional ground penetrating radar (GPR) formulae. Using conventional GPR Range Formulae, this 40 mm core of quartizite with a mean dielectric constant ($\epsilon_R = 5$) should have produced an equivalent time range length on the image of 0.54ns, but the 10:1 factor stretched the time range because the beam was slowed down in the telescope and this resulted in a time range image spanning 5.4ns. This is considered by the inventor to be a tube geometry and dielectric lens effect, and will assist in the near range focusing of radio-wave cameras and microscopes as well as radio-wave telescopes for mapping deep below ground level or the sea-bed.

The above description relates to particular embodiments of the invention. In general, the ranges of parameters selected for the volume of the test chamber, the bandwidth, data acquisition times and spectral time windows and in particular the dielectric lensing substances may all vary and may be dependent on the type of material to be typecast.

Furthermore, if the dielectric properties of the cladding material surrounding the antenna of the telescopes vary under given conditions, for example if the dielectric constant is thermally dependent, such as is the case with barium titanate, then it is possible to detect such conditions by staring at the substance and monitoring the change in the received spectral data. This could enable the thermal conditions of subterranean structures/substances/objects to be determined. Other dielectrics of interest include lead

zirconate titanate (PZT) and ammonium dihydrogen phosphate.

For the removal of doubt, wherever specific reference has been made to a substance, the term may be taken to include the objects, liquids and powders as well as larger scale geological and marine features.

While several embodiments of the present invention have been described and illustrated, it will be apparent to those skilled in the art once given this disclosure that various modifications, changes, improvements and variations may be made without departing from the spirit or scope of this invention.

CLAIMS

1 A radar apparatus (1) having transmitter means (2,201) for emitting a pulsed radar signal, receiver means (3,202) for receiving a radar signal, filter means and/or tuning means to control at least one spectral characteristic of the emitted and/or the received radar signals, the radar apparatus (1) further including:

a transmitter cavity (5a,227) substantially surrounding at least one element (6a,7a,230) of a transmitting antenna;

a receiver cavity (5b,227) substantially surrounding at least one element (6b,7b,230) of a receiving antenna; and

a dielectric cladding material at least partially surrounding at least one element (6a,7a,6b,7b,230) of at least one of said transmitting and receiving antennae.

2 Radar apparatus (1) as claimed in Claim 1, further including:

a lens (9a,9b,224 and 225) provided at the aperture end of at least one of the transmitting and/or receiving cavities (5a,5b,227) thereby to focus radiation transmitted therethrough.

3 Radar apparatus (1) as claimed in either Claim 1 or 2, wherein at least one interior dimension of each of the transmitting/receiving cavities (5a,5b,227) is proportional to at least one element (6a, 7a, 6b, 7b,230) of an antenna provided therewithin.

4 Radar apparatus (1) as claimed in Claim 3, wherein the transmitter cavity comprises a telescope (200,201) having a substantially cylindrical internal boundary

wall forming a cathode element of the transmitting antenna and substantially surrounding an anode element (230) of the transmitting antenna.

5 Radar apparatus (1) as claimed in any preceding claim, wherein the receiver cavity comprises a telescope (200,202) having a substantially cylindrical internal boundary wall forming the cathode element of the receiving antenna and substantially surrounding the anode element (230) of the receiving antenna.

6 Radar apparatus (1) as claimed in any one of Claims 4 or 5, wherein the interior diameter D_T of the telescope cavity (200,201,202) is an integer multiple of the diameter D_A of the anode element (230) of the antenna disposed therewithin.

7 Radar apparatus (1) as claimed in any one of Claims 4 to 6, wherein the interior length L_T of the telescope cavity is an integer multiple of the length L_A of the anode element (230) of the antenna disposed therewithin.

8 Radar apparatus (1) as claimed in Claim 7, wherein the internal geometry of transmitter telescope (200,201) and the receiver telescope (200,202) are in the same proportion.

9 Radar apparatus (1) as claimed in any preceding claim wherein the transmitter cavity (5a,201) and the receiver cavity (5b, 202) are arranged with the longitudinal elements of the cavities axially aligned and the apertures of the cavities facing each other.

10 Radar apparatus (1) as claimed in any of Claims 1 to 8 wherein the transmitter cavity (5a,201) and the

receiver cavity (5b, 202) are arranged with the longitudinal elements of the cavities aligned parallel to each other and with the apertures of the cavities facing the same direction.

11 Radar apparatus (1) as claimed in any preceding claim, wherein the transmitter antenna and the receiver antenna are arranged in a cross-polarised configuration.

12 Radar apparatus (1) as claimed in any preceding claim, wherein the receiver (3) is connected to the filter means and/or tuning means to enable the receiver (3) to be capable of detecting in the received signal a resonant condition.

13 Radar apparatus (1) as claimed in any preceding claim, wherein the emitted and received signals occupy the ultra-wide band radio portion of the electromagnetic spectrum.

14 Radar apparatus (1) as claimed in claim 13, wherein the emitted and received radar signals occupy between 5 MHz and 2500 MHz.

15 Radar apparatus (1) as claimed in claim 13 or 14, wherein the received signal ranges from 5 MHz to 12 GHz.

16 Radar apparatus (1) as claimed in any preceding claim, wherein the dielectric properties of the dielectric cladding material are temperature dependent.

17 Radar apparatus (1) as claimed in any preceding claim, further including:

an analogue-to-digital (AD) converter (22) which

digitises an analogue signal output from the receiver (3); and

computational means (23) for receiving the digitised output of the AD converter, wherein the computational means (23) is provided with suitable software capable of performing spectral analysis on the received digitised signal to determine at least one selected parameter in a parameter space to substantially uniquely represent the substance.

18 Radar apparatus (1) as claimed in Claim 17, wherein the computational means (23) is further provided with software suitable for distinguishing a parameter space representing a particular substance from at least one other parameter space representing another substance.

19 Radar apparatus (1) as claimed in either Claim 17 or 18, wherein, in addition to at least one digitised output signal relating to the positional and/or compositional characteristics of a substance represented by the received signal, the AD converter (22) provides a fourth signal relating to voice data co-recorded with the acquired radar data.

20 Radar apparatus (1) as claimed in any one of Claims 17 to 19, wherein the said at least one selected parameter is determined in real-time during a data acquisition period.

21 Radar apparatus (1) as claimed in Claim 18, wherein the said parameter space is distinguished in real-time during a data acquisition period.

22 Radar apparatus (1) as claimed in any one of Claims 17 to 21, wherein the time interval for sampling

data is less than 100 msec.

23 Radar apparatus (1) as claimed in any one of Claims 17 to 22, further including display means (23) for displaying at least one selected parameter space or other information representing the spectral analysis of the digitised signal.

24 Radar apparatus (1) as claimed in any one of Claim 17 to 23, wherein the computer is provided with a suitable storage means (24) for the storage and retrieval of said parameter space.

25 Radar apparatus (1) as claimed in any preceding claim, wherein the radar apparatus (1) is portable.

26 Radar apparatus (1) as claimed in any preceding claimed wherein the radar apparatus (1) is provided on a land vehicle and/or a sea-vehicle and/or a sea-platform.

27 Radar apparatus (1) as claimed in any preceding Claim, further including an irradiation chamber (4,100).

28 Radar apparatus (1) as claimed in Claim 27, wherein the transmitting cavity (5a, 201) and receiving cavity (5b, 202) at least partially form the irradiation chamber (4,100).

29 Radar apparatus (1) as claimed in either Claim 27 or 28, wherein the irradiation chamber (4,100) is disposed substantially between the transmitter telescope (5a,201) and the receiver telescope (5b,202).

30 A method of typecasting a substance by

spectrometric analysis of the substance using the radar apparatus (1) as claimed in any preceding claim comprising:

selectively tuning the transmitter (2) to generate at least one standing wave condition and/or resonant signal condition in the spectral response received from the substance irradiated by the radar signal emitted by the transmitter (2);

configuring the radar apparatus (1) according to any one preceding claim so that the analogue signal received by the radar apparatus (1) represents said at least one resonant condition;

detecting the analogue signal representing the spectrum of radiation set up under resonant conditions;

converting the analogue signal into digital form;

analysing said digitized spectrum to determine at least one selected parameter representing the composition of the substance;

suitably storing said selected parameter in a retrievable form, wherein said selected parameter forms part of a parameter space such that the substance which has substantially induced the spectral characteristics of the received signal can be uniquely represented in that parameter space.

31 A method of typecasting as claimed in Claim 30, wherein sufficient radiation is transmitted into the substance for standing wave oscillations excited within the substance itself to be detected by the receiver (3).

32 A method of typecasting as claimed in Claim 30 or 31 when dependent on any one of Claims 27 to 29 further comprising the steps of:

placing the substance to be typecast into the chamber (4,100);

selectively tuning the emitted radar signal so that the radiation transmitted can induce the resonant condition;

detecting an analogue signal representing the spectrum of radiation set up under resonant conditions within the chamber (4,100);

converting the analogue signal into digital form; and

analysing said digitized spectrum to determine at least one selected parameter representing the composition of the sample placed within the chamber (4,100).

33 A typecasting method according to either Claim 31 or Claim 32 further including the step of storing the selected parameter in a retrievable electronic format.

34 A method of identifying an unknown substance using the radar apparatus (1) as claimed in any one of Claims 1 to 29 comprising the steps of the typecasting method as claimed in any one of Claims 30 to 33 and further including the step of:

collating at least one parameter space previously determined and stored in a suitable memory means (24) of a computer (23) with the parameter space acquired which represents the unknown substance; and

correlating the two aforesaid parameter spaces to determine whether they are substantially equivalent.

35 A surveying method of locating and/or identifying unknown objects/substances in field conditions using the radar apparatus (1) as claimed in Claim any one of Claims 1 to 29 wherein the radar apparatus (1) provides means for determining a parameter space which represents a substance in the presence of other parameter spaces representing other substances as the

radar apparatus moves relative to the substances scanned, the surveying method being otherwise as the steps provided in Claim 34.

36 A surveying method as claimed in Claim 35, wherein the radar apparatus (1) is moved relative to the area to be surveyed.

37 A surveying method as claimed in any one of Claims 35 to 36, further identifying the type of substance/object by correlation with selected spectral parameters previously acquired and stored in a database structure.

38 A surveying method as claimed in any one of Claims 35 to 37, wherein to determine the position of a structure using the radar apparatus (1) as claimed in any one of Claims 1 to 29, the said selected at least one parameter data is converted into image data and is displayed on a display means (23).

39 A surveying method including the steps claimed in Claims 34 to 38 and further including:

the step of locating the zero time position in the received analogue radar signal to obtain range represented by the received signal.

40 A method as claimed in Claim 39 wherein the structure imaged is a concealed structure.

41 A method as claimed in Claim 40 wherein the concealed structure is subterranean.

42 A method as claimed in Claim 41 wherein the subterranean structure is located below ground level and/or below the sea-bed.

43 A method of determining the internal state of a substance by monitoring the variation of their parameter space as recorded in any one of claims 30 to 42.

44 Radar apparatus (1) substantially as described hereinabove and with reference to the accompanying drawings.

45 A method of typecasting a substance as described hereinabove and with reference to the accompanying drawings.

46 A method of locating a substance as described hereinabove and with reference to the accompanying drawings.

47 A method of surveying a substance as described herereinabove and with reference to the accompanying drawings.

48 A method of monitoring the movement of a concealed structure as described hereinabove and with reference to the accompanying drawings.

ABSTRACT

Radar apparatus (1) having transmitter means (2) for emitting a pulsed radar signal, receiver means (3) for receiving a radar signal, filter means and/or tuning means to control a least one spectral characteristic of the emitted and/or the received radar signals, further includes a transmitter cavity (5a,201) substantially surrounding at least one element (6a,7a,230) of a transmitting antenna; a receiver cavity (5b, 202) substantially surrounding at least one element (6b,7b, 230) of a receiving antenna; and a dielectric cladding material at least partially surrounding at least one element (6a,7a,6b,7b, 230) of at least one of said transmitting and receiving antennae.

The diameter D_A of the anode element 230 is an exact multiple of the internal diameter D_T of the telescope tube 227. The anode element 230 also protrudes into the interior of the tube 227 by a distance L_A which is an exact multiple of the total reflecting distance L_T from the back wall reflector 232 to the front wall reflecting ring 226.

(FIGURE 5)

/u/mur/specs22/p22111-

1/13

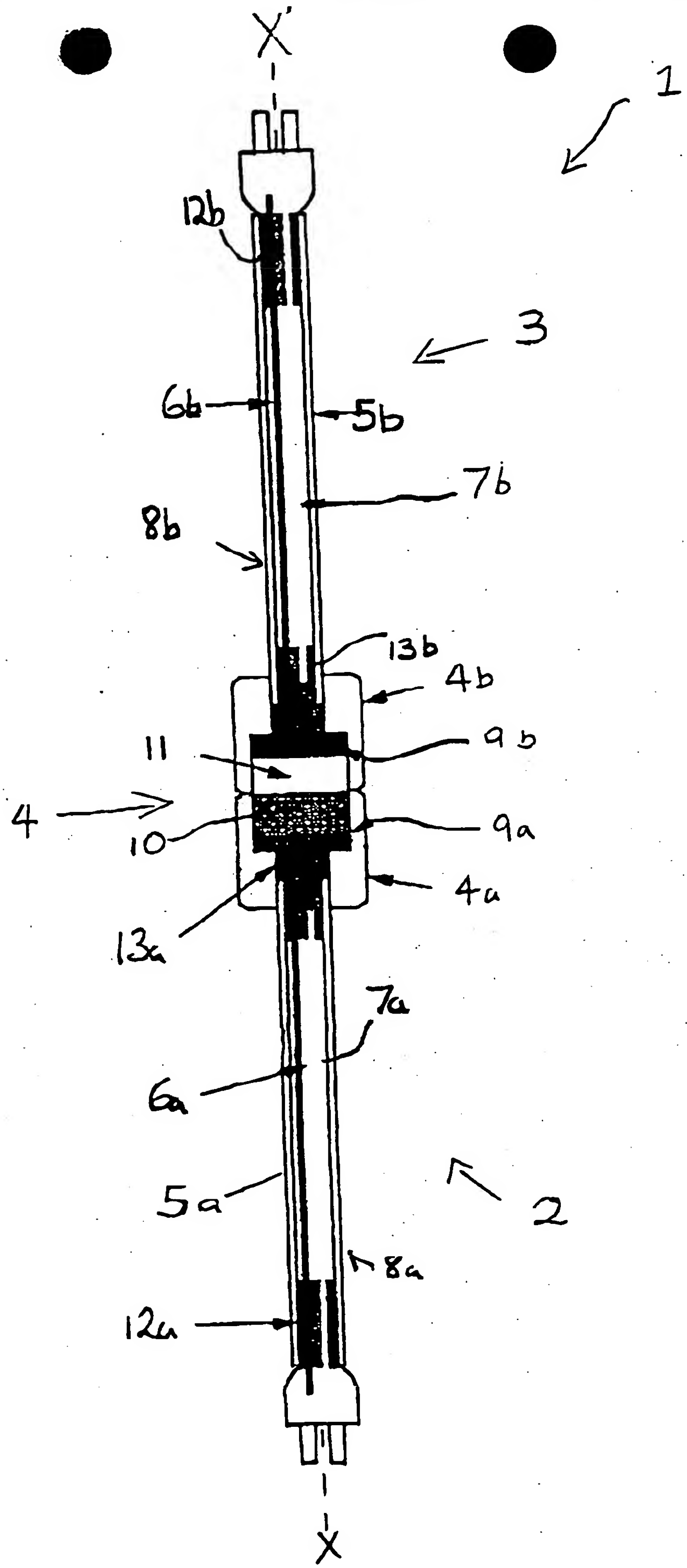


FIG 1

2/13

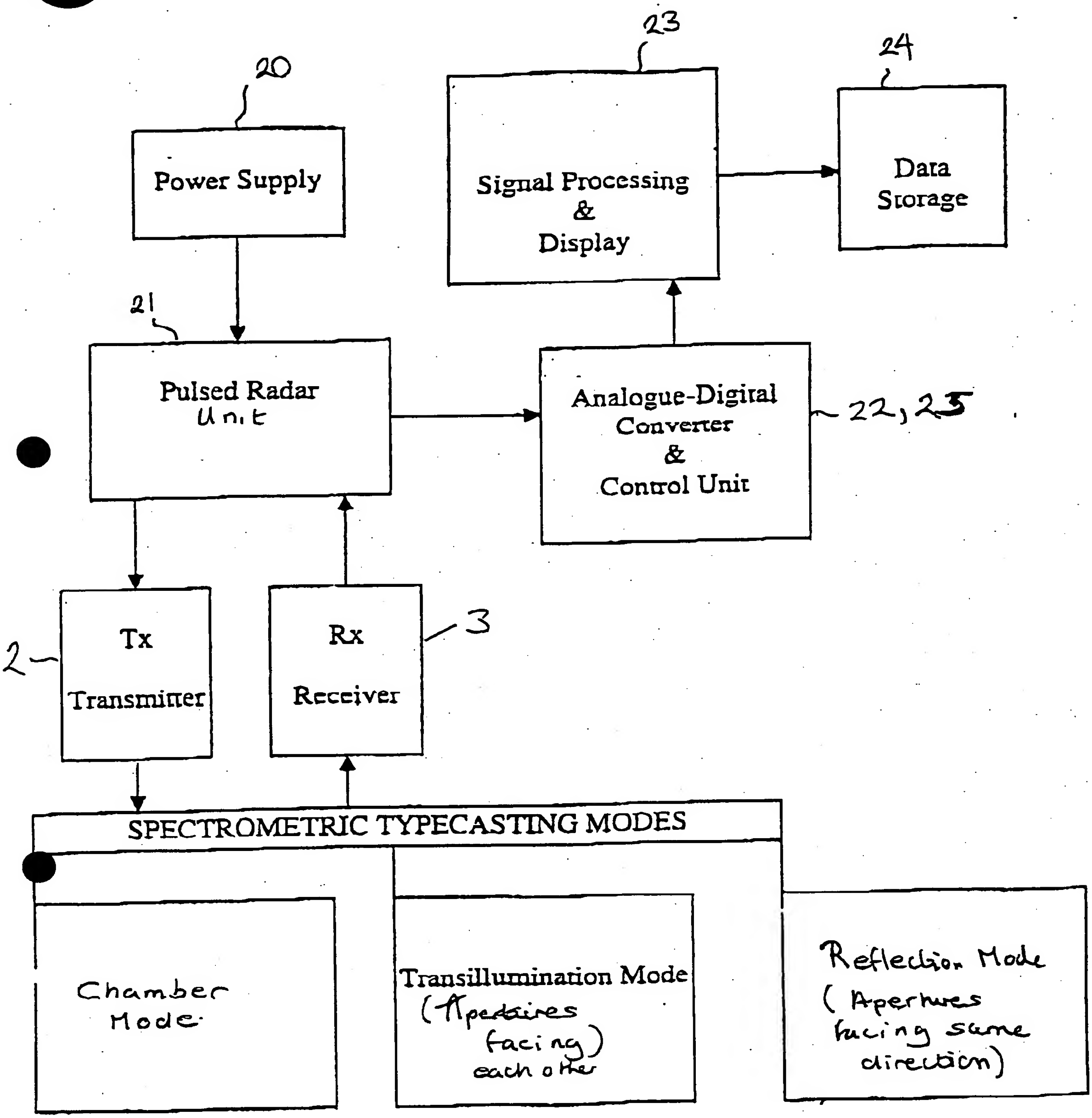
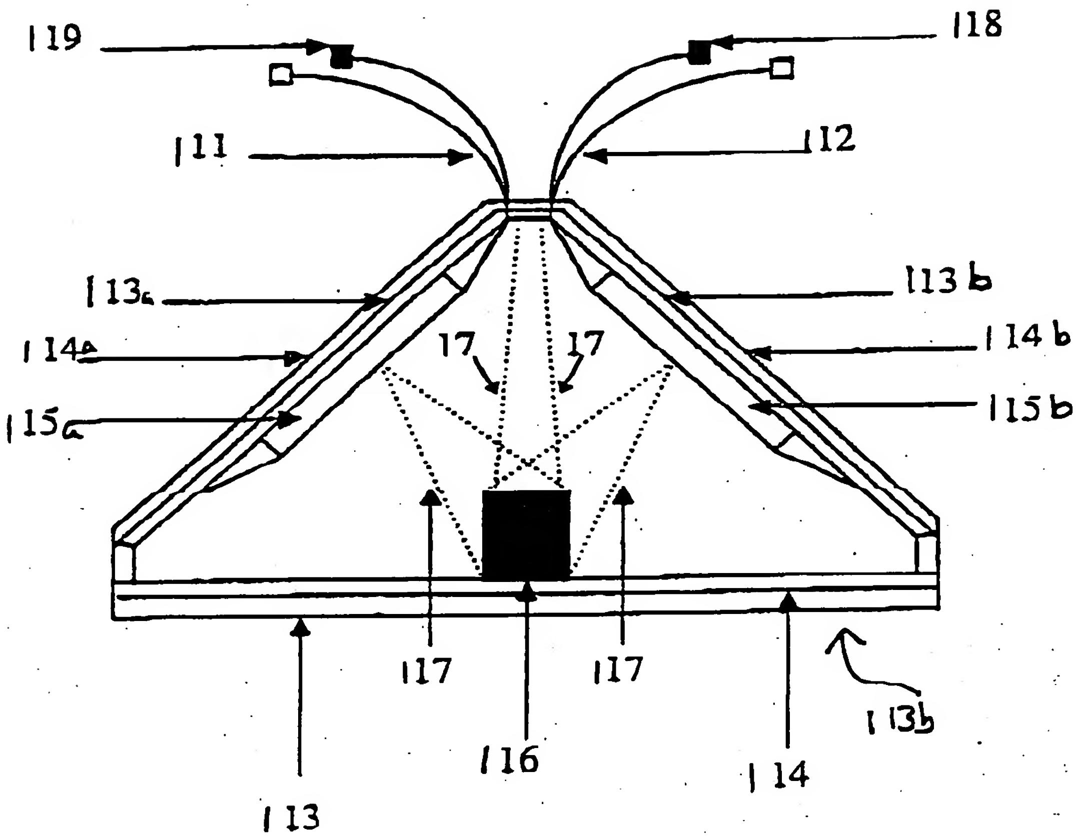

20
Power Supply
23
Signal Processing
&
Display
24
Data
Storage
21
Pulsed Radar
Unit
Analogue-Digital
Converter
&
Control Unit
22, 25
2
Tx
Transmitter
Rx
Receiver
3
SPECTROMETRIC TYPECASTING MODES
Chamber
Mode
Transillumination Mode
(Apertures
facing)
each other
Reflection Mode
(Apertures
facing same
direction)

FIG 2



↑ 100a

FIG 3A

Received 07-09-99 02:44pm From-+01413078401 To-THE PATENT OFFICE Page 56

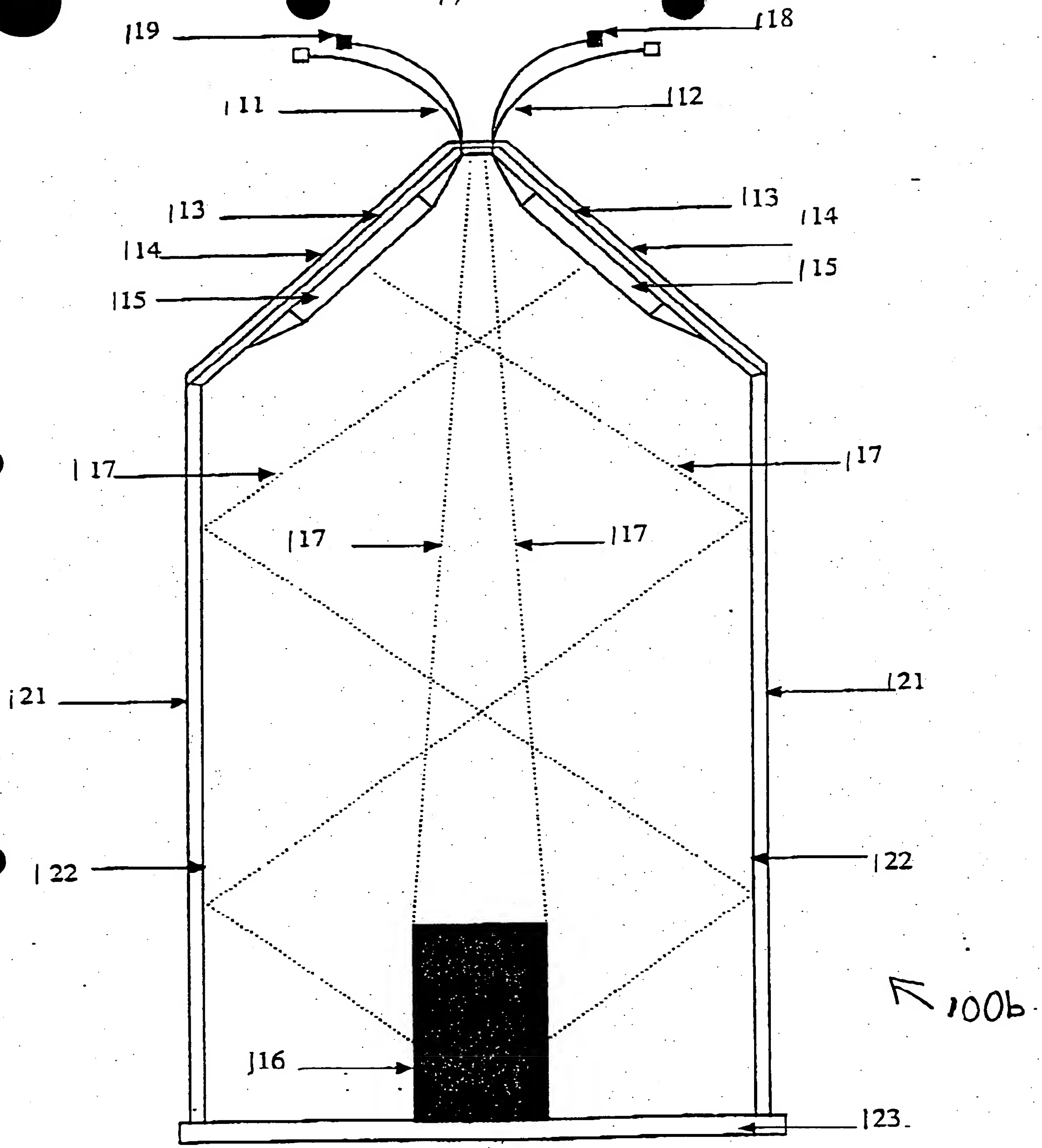

119
118
111
112
113
113
114
114
115
115
117
117
117
117
121
121
122
122
116
123
100b

FIG 3B.

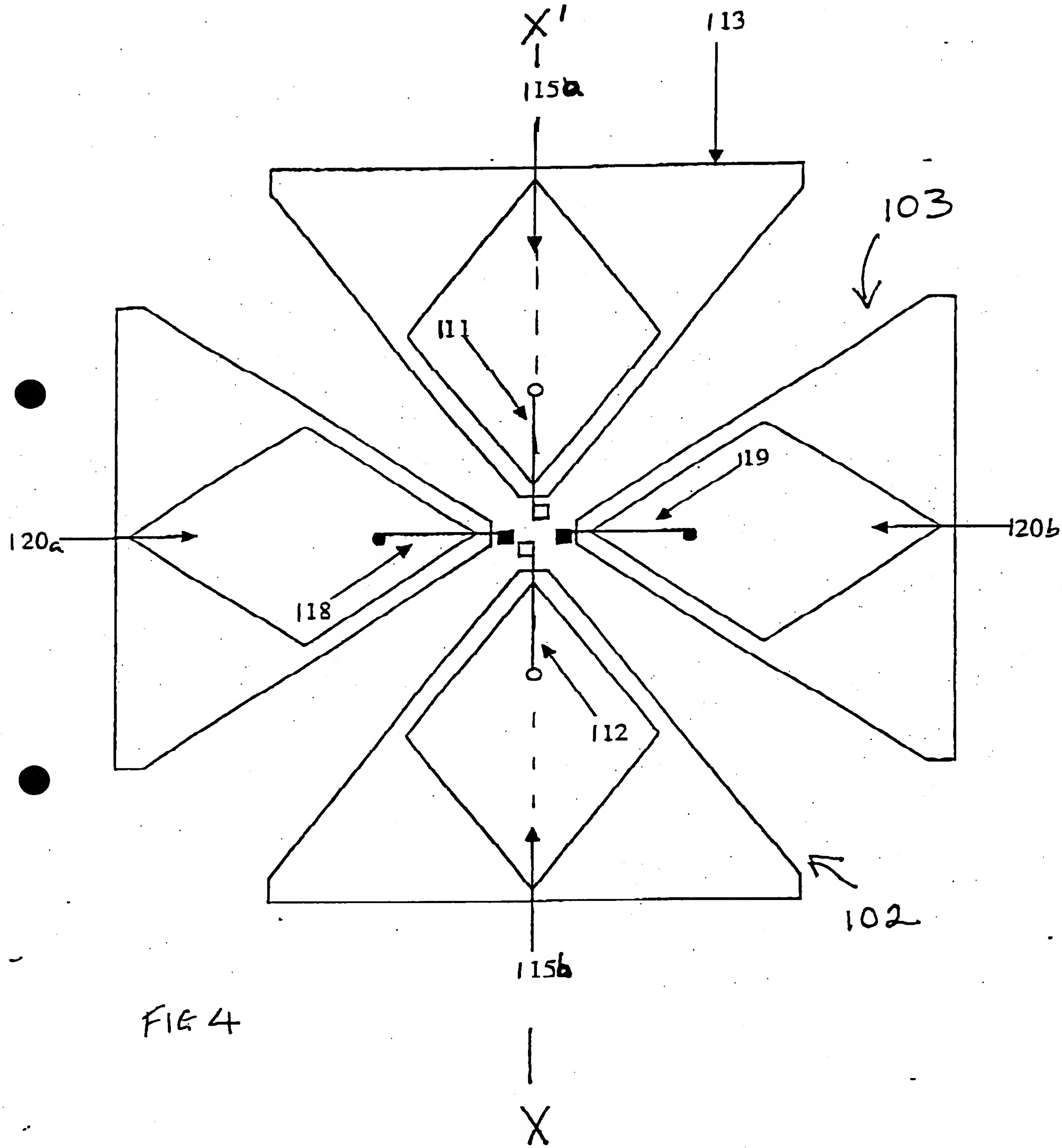


FIG 4

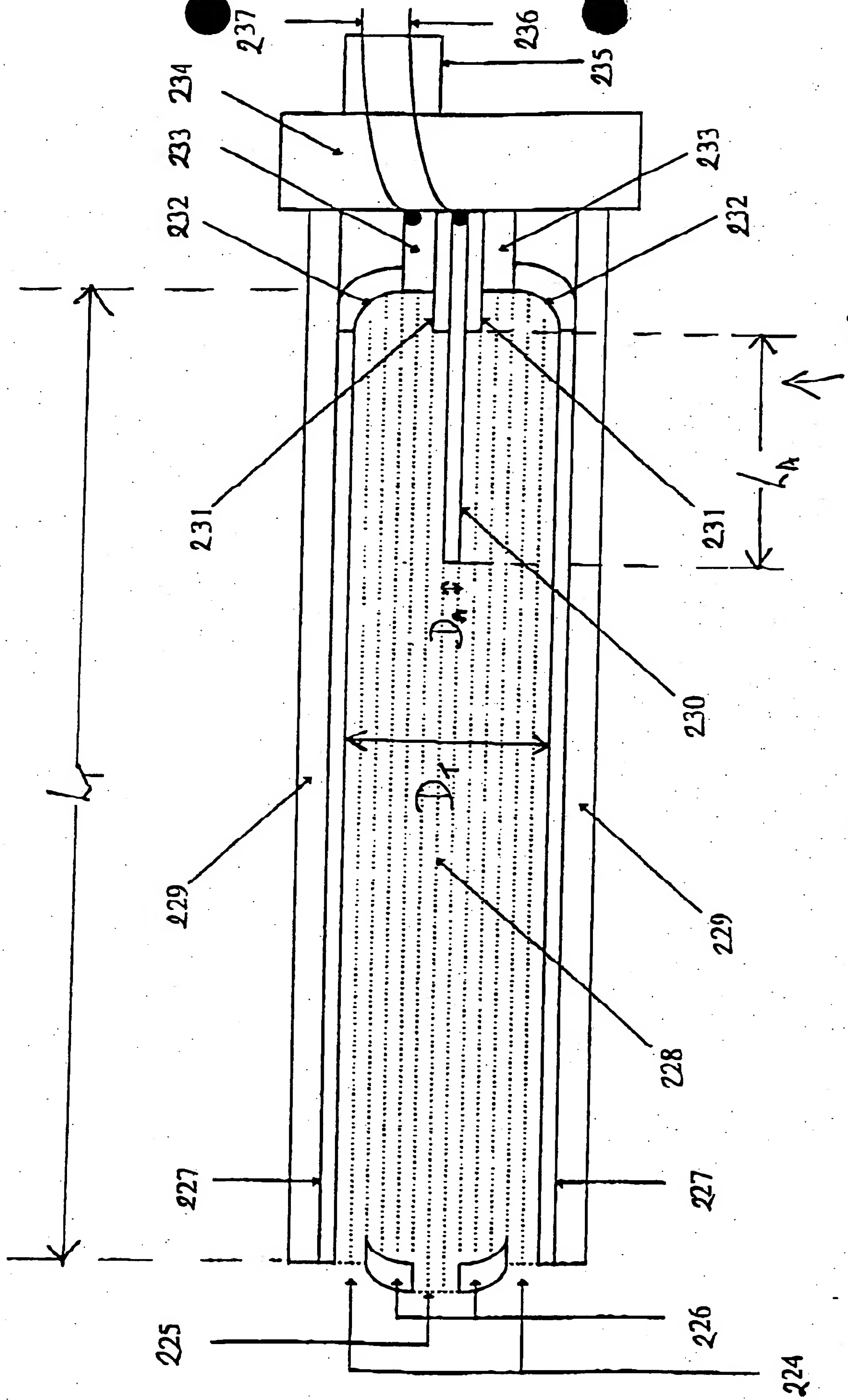

237
236
235
234
233
233
232
232
231
231
230
229
229
228
227
227
226
225
224
200'
L
L_A
D_A
D_T

FIG 5

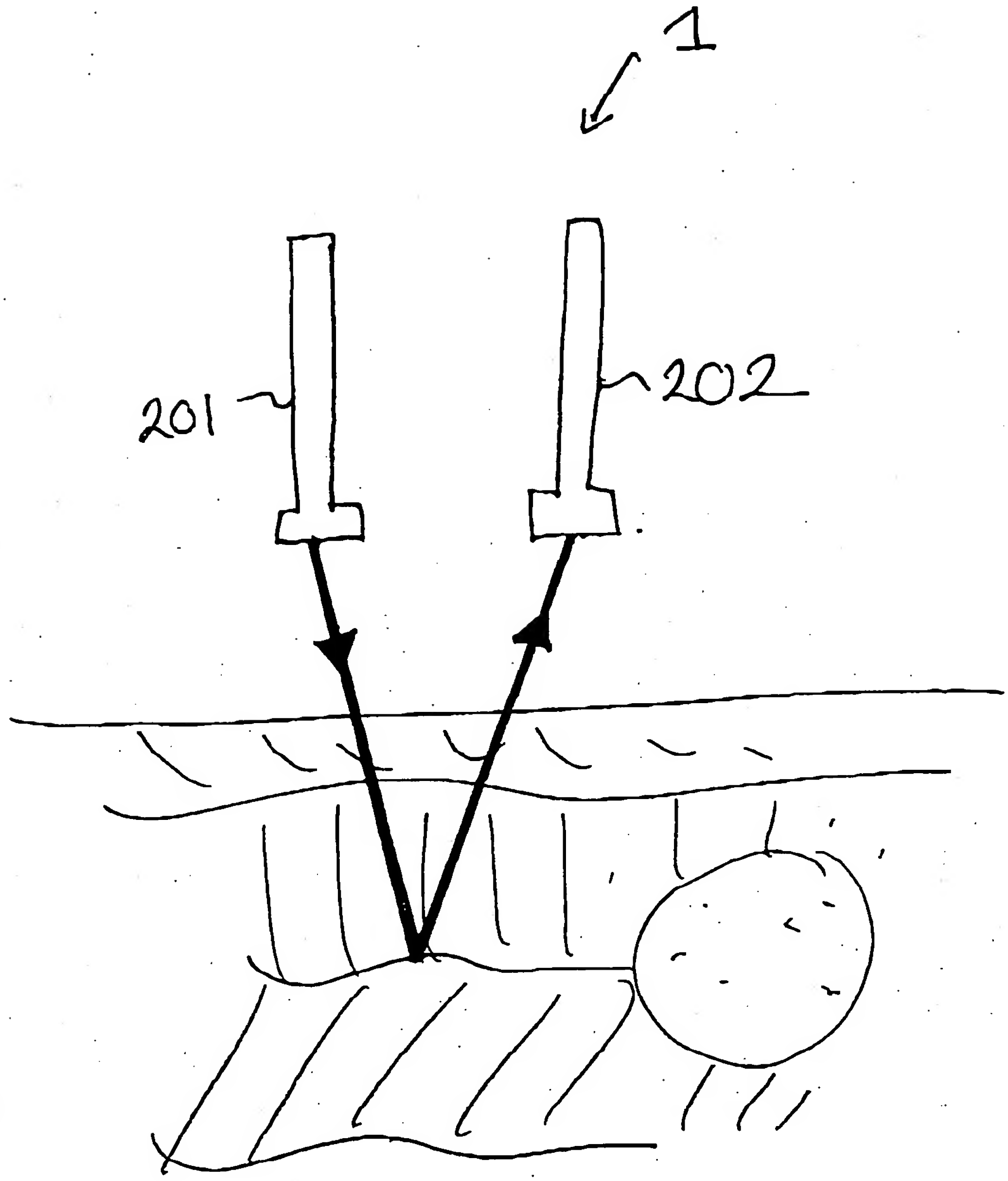


Fig 6A

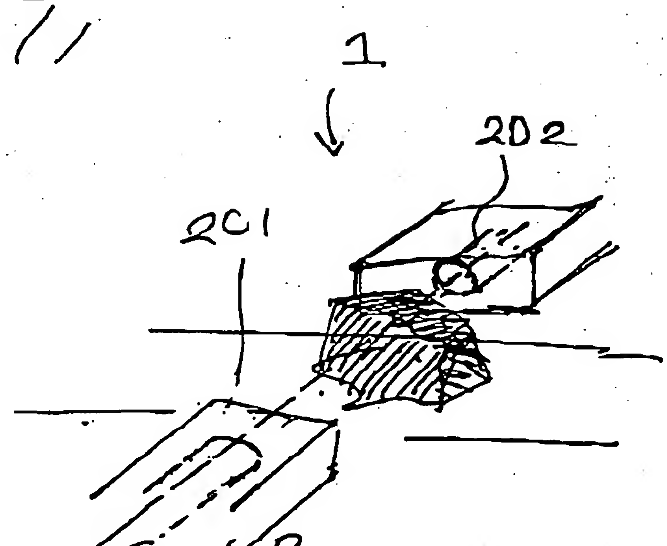


Fig 6 B

8/13

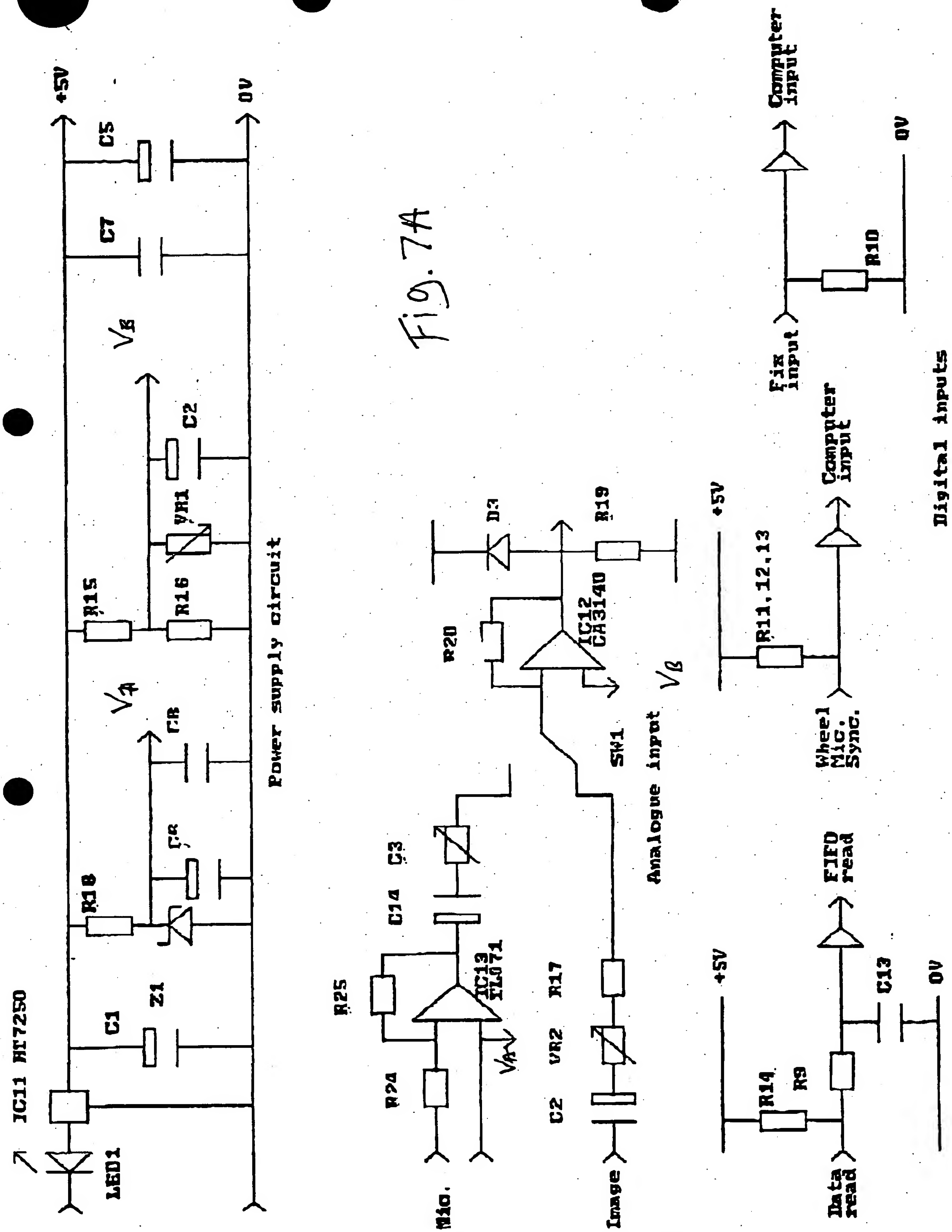

+5V
0V
C5
C7
VB
C2
VR1
R15
R16
VA
C8
R18
Z1
C1
IC11 HT7250
LED1
Power supply circuit
D3
R19
R20
IC12 CA3140
SW1
Analogue input
C3
C14
R25
IC13 TL071
R17
VR2
R24
Mic.
Image
Computer input
R10
Fix input
Digital inputs
R11,12,13
Wheel Mic. Sync.
FIFO read
C13
R14
R9
Data read

Fig. 7A

9/13

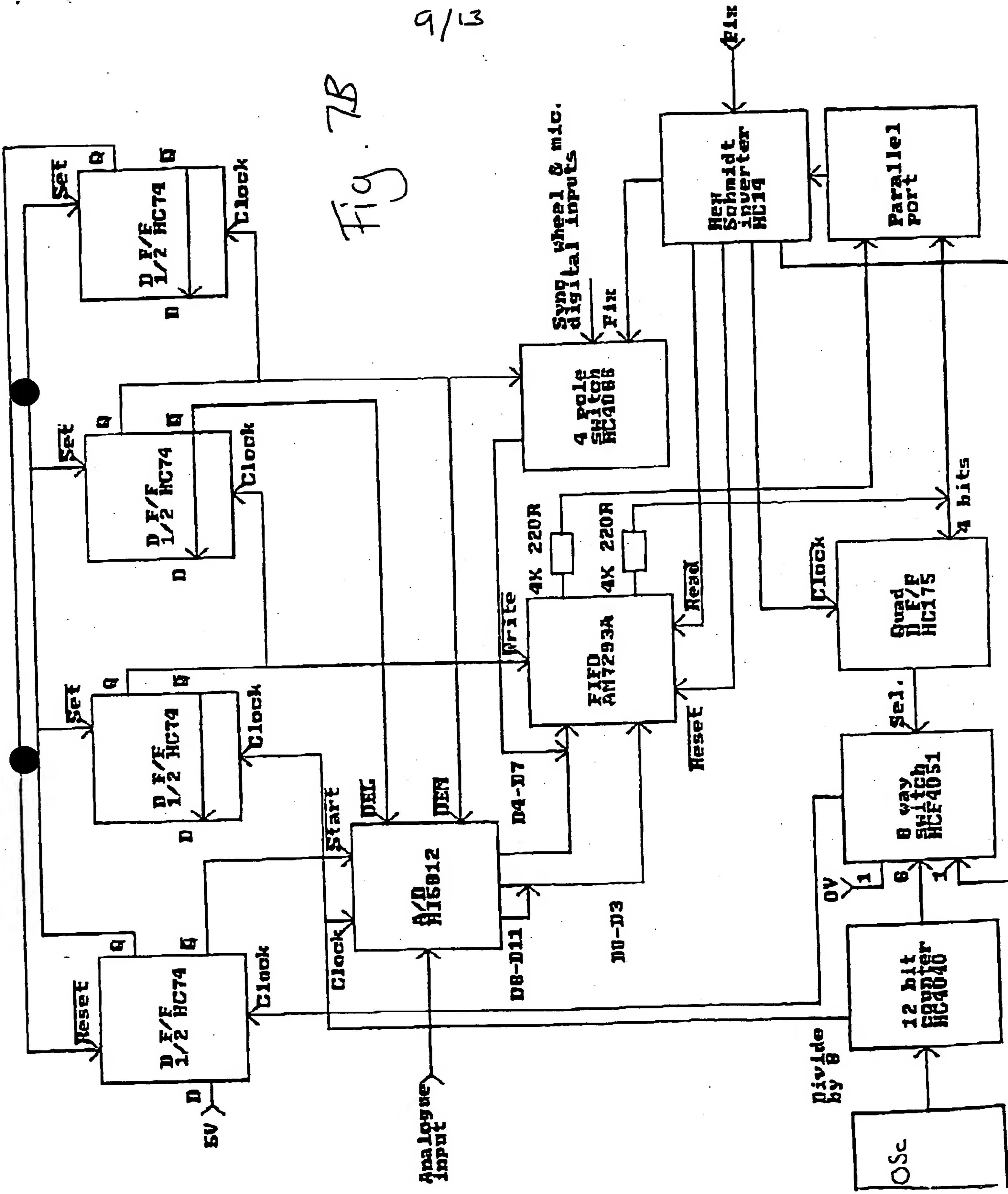

D F/F 1/2 HC74
Set
Reset
Q
Clock
D
5V
4 pole switch HC4066
Sync wheel & mic. digital inputs
Fix
Hex Schmidt inverter HC14
Parallel port
4K 220R
Write
Read
FIFO AM7293A
Reset
Quad D F/F HC175
4 bits
Sel.
8 way switch HCF4051
A/D HI5812
Start
D4-D7
D0-D3
D8-D11
12 bit counter HC4040
Divide by 8
OSc
0V
Analogue input

Fig 7B

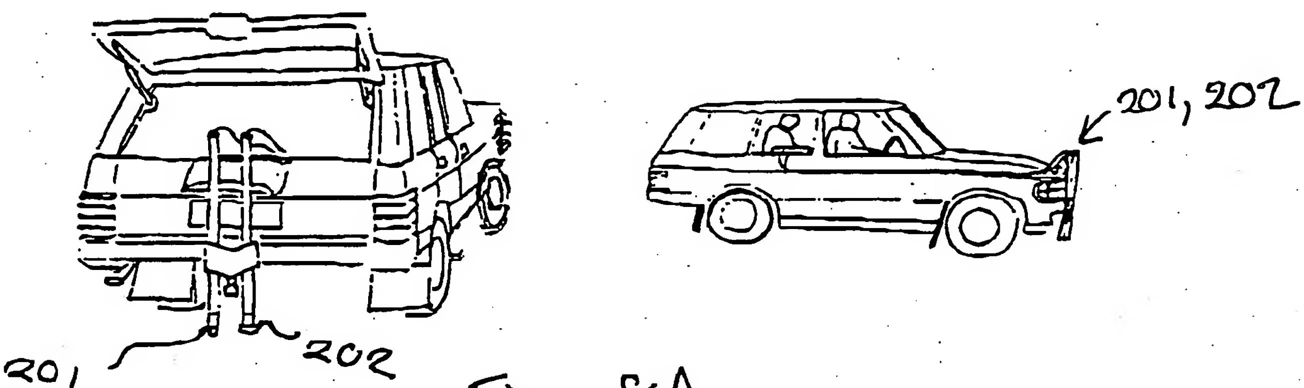


Fig. 8A

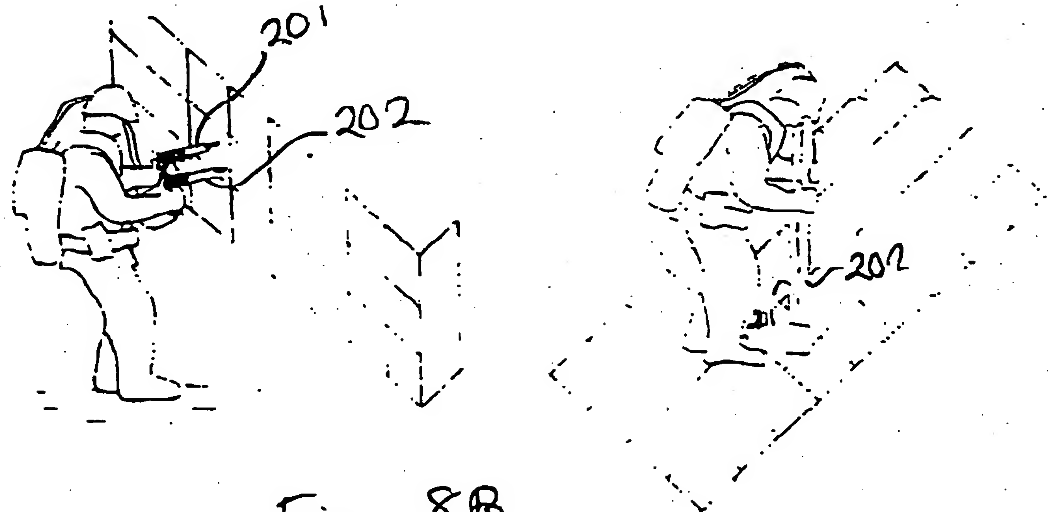


Fig. 8B

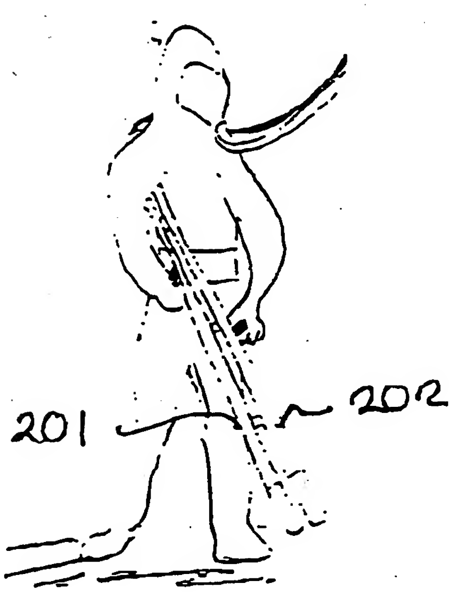


Fig. 8C

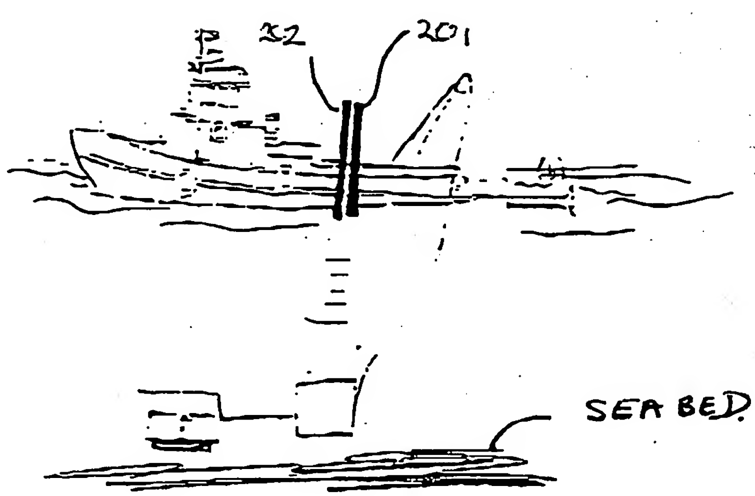


Fig. 8D

07-09-99 03:01pm From-MURGITROYD +01413078401 T-645 P.64/66 F-965

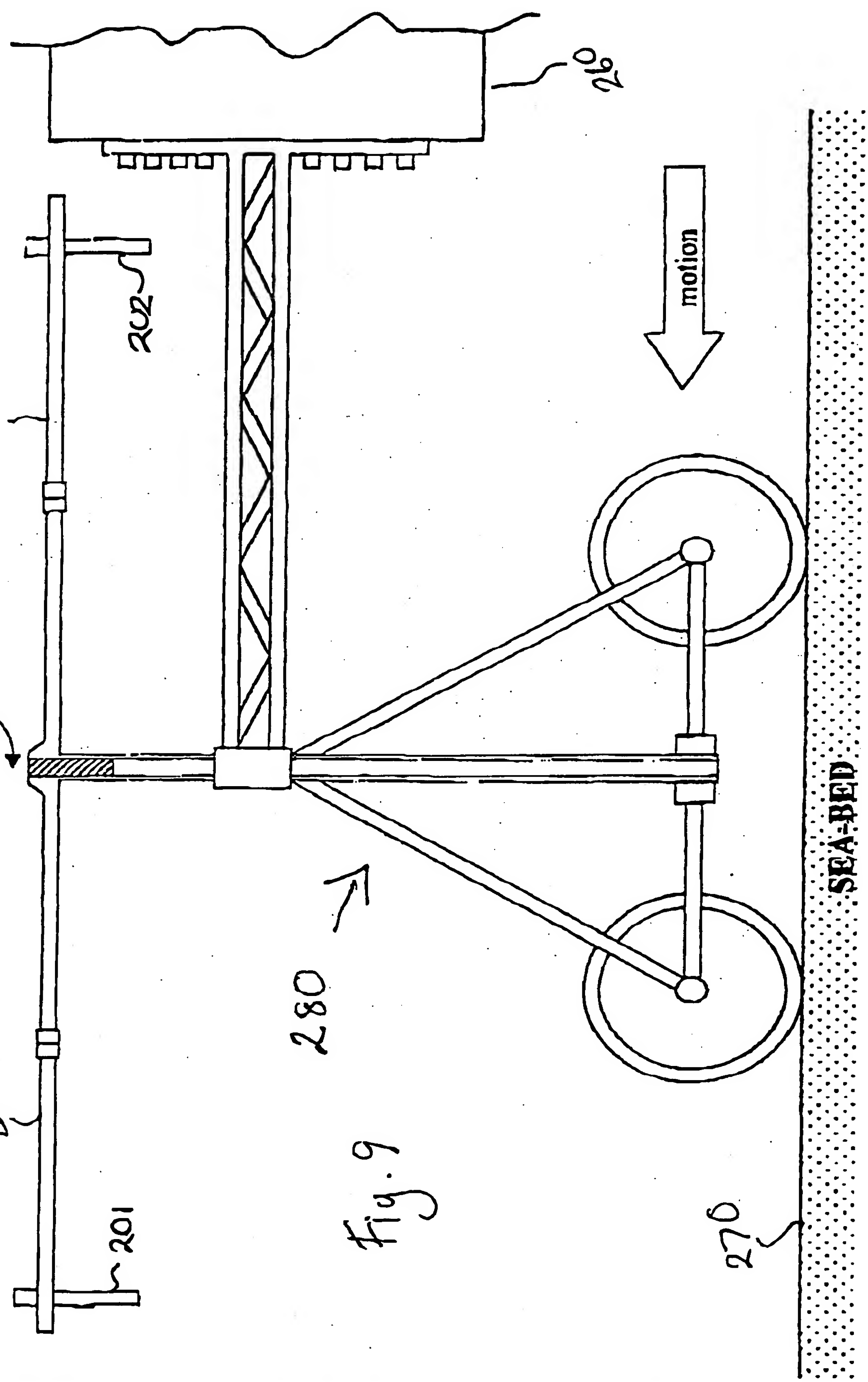
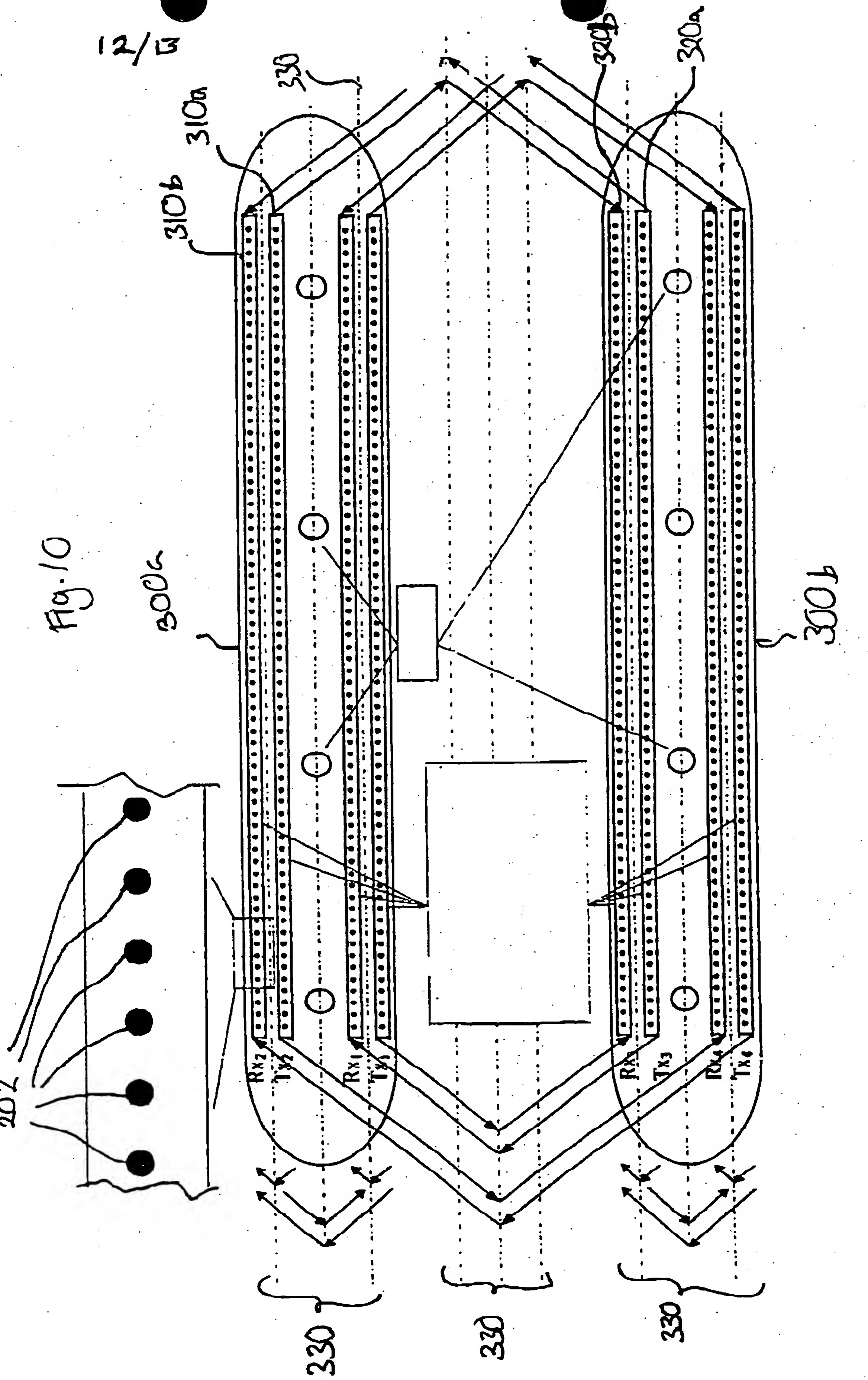


Fig. 9

Received 07-09-99 02:44pm From-+01413078401 To-THE PATENT OFFICE Page 64

12/13



300a
300b
310a
310b
320a
320b
330
330
330
330
202
Rx2
Tx2
Rx1
Tx1
Rx3
Tx3
Rx4
Tx4

Fig. 10

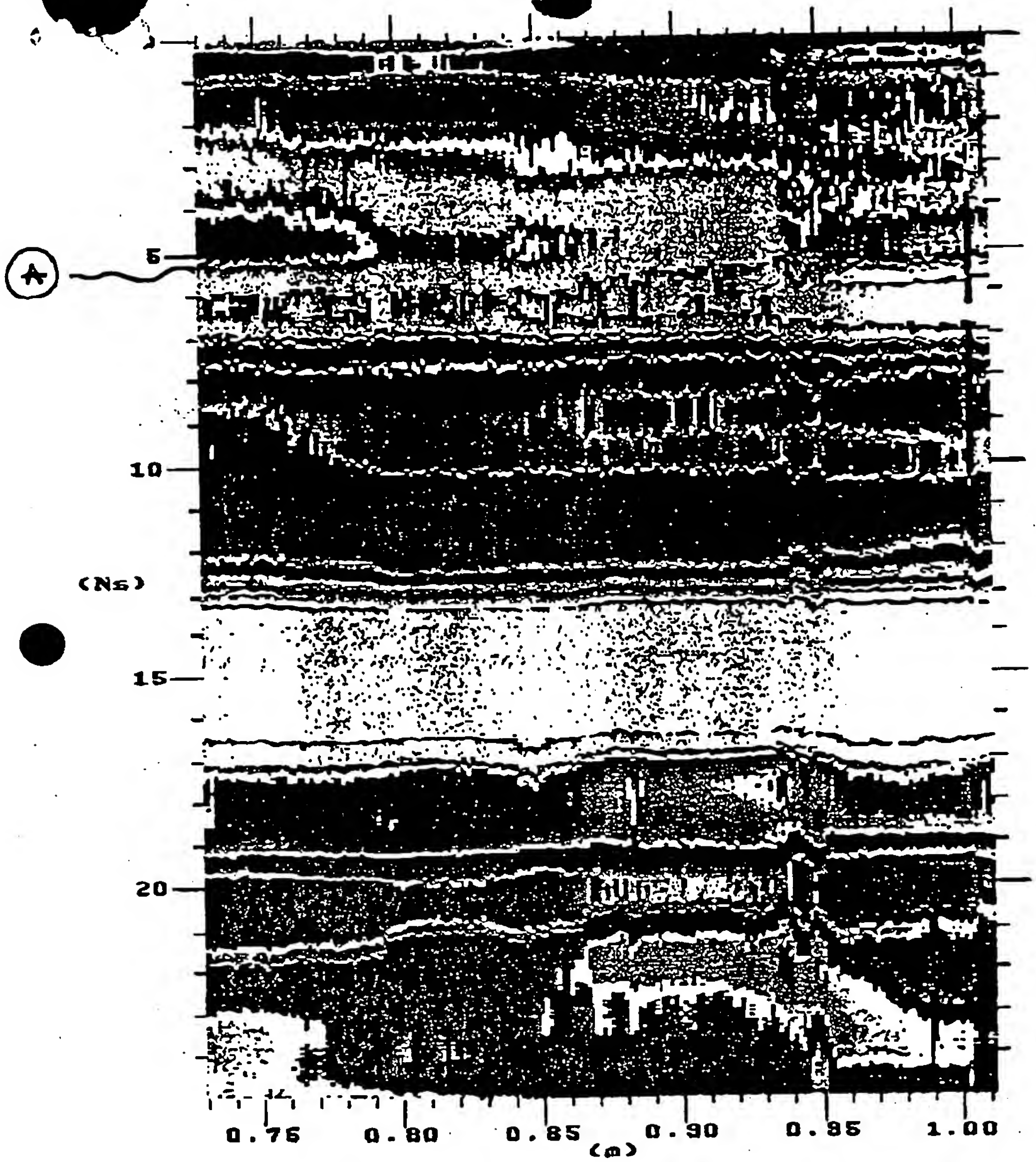


Fig. 11

THIS PAGE BLANK (USPTO)